JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXI. APRIL, 1886. No. 4.

THE FRANKLIN INSTITUTE is not responsible for the statements and opinions advanced by contributors to the JOURNAL.

TORNADO STUDY—ITS PAST, PRESENT AND FUTURE.

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[*A Lecture delivered before the* FRANKLIN INSTITUTE, *November 27, 1885.*]

The systematic study of tornadoes as such, and as the term is now technically applied to severe local storms, is of comparatively recent origin. The funnel-shaped cloud, however, had been observed and described by intelligent persons in this country, so far as our records show, as far back as 1761. The storm in question occurred at Charleston, S. C., and was one of remarkable violence. About 2 P. M., on the fourth of May, this terrible phenomenon was first seen by many of the inhabitants of Charleston coming down Wappoo Creek, the cloud resembling a large column of smoke and vapor. In the course of its path every tree and shrub was torn up. Great quantities of leaves, branches, and timbers were seen furiously driven about and agitated in the body of the moving column of cloud. The sky was overcast and cloudy all the

forenoon. About 1 o'clock it began to thunder, followed by heavy clouds and more thunder. The day (particularly in the afternoon before the storm) was very sultry and oppressive. Shortly after the storm, the wind was "quite fallen," the sun shone out and the sky was clear and serene. The direction of progressive movement of the cloud was from S. W. to N. E.

The width of path is given as 300 fathoms (about 1,800 feet). The account further informs us that though such storms were very unusual in Charleston, yet vestiges of the tremendous power of the whirling cloud could be seen in the wooded country about the town, both in that and in neighboring "provinces."

Here we have a most interesting and intelligent account of a tornado occurring nearly 125 years ago, and evidence of the appearance of these storms at a much earlier date, in South Carolina.

Another remarkable tornado was observed and described by the Rev. Dr. Stiles, of Yale College, as occuring at Northford, Conn., June 19, 1794. The observer was about 100 yards distant from the cloud while it passed. It was a circular figure whirling most violently upon its centre. From the midst of the cloud issued a "vortex of air," much in the form of an hour glass, which alternately contracted and expanded from ten to twenty rods. The hour-glass form of the cloud at the earth, had constant communication with the cloud above. When it contracted it became less violent, but when it expanded, the scene was frightful and destruction filled the air.

In 1842, Prof. Loomis, of Yale College, prepared and published in Silliman's Journal, Vol. 23, a list of 19 tornadoes, occurring during the years 1823 to 1842, in the following States: Mississippi, 4; Ohio, 3; Tennessee, 2; New York, 4; Connecticut, 1; Rhode Island, 1; North Carolina, 1; New Jersey, 1; and Alabama, 1.

In Europe, we find very early records of storms that appeared to possess the characteristics of our tornadoes of to-day. In A. D. 793, "dire fore-warnings came over the land of the Norththumbrians, (England) and terribly terrified the people; these were excessive whirlwinds, with dragon-like tails." Here the spout-like form of the cloud is referred to.

In the year 1090, it is recorded that in England a violent tornado overturned 606 houses.

About the first specific date of a storm is the one that occurred

on the fifth of October, 1091, in England. It passed from S. W. to N. E., and the sky was dreadfully dark. Many churches fell, and in London over 500 houses were destroyed.

On the eighth of April, 1838, a tornado passed within three miles of Calcutta, British India; width of path, one-quarter mile; direction of movement, S. 37° E. The tiles of the terraces laid in the best cement were ripped up as if by suction. As a most extraordinary proof of the lateral force of the wind, a slight bamboo was driven horizontally through one of the raised tiled walks which pierced through the whole breadth, breaking the tiles on both sides. These tiles were made of baked earth, five feet thick. The tornado formed about 2 P. M., and passed through twenty-six villages from Arundpore to Hurreennabhee, a distance of sixteen miles, destroying 1,245 houses, 215 people and 533 head of cattle.

At Chatenay, near Paris, in June, 1839, a violent tornado occurred shortly after mid-day. The cloud assumed the form of a funnel, the small end reaching the earth. Everything in its path was completely swept from the earth.

This record might be greatly augmented had I the time to devote to it, in this brief résumé of the subject.

We thus find that the tornado (the unmistakable and characteristic funnel-shaped cloud) has been observed and recorded more or less faithfully, for over 130 years in this country, and for centuries in Europe and parts of Asia.

Let us consider for a moment the names of those who have given some attention to this subject, in most cases, prior to the commencement of the study by the Signal Service. I refer now to the United States.

Rev. Dr. Stiles, of Yale College, prepared a brief description of the tornado of June 19, 1794, at Northford, Conn.

Prof. Wm. C. Redfield made a brief study of the tornado of August 30, 1838, at Providence, R. I.

Prof. Robert M. Hare, of the University of Pennsylvania, in 1838.

Prof. Olmsted, of Yale College, a tornado at New Haven, Conn., July 31, 1839.

Prof. Elias Loomis, of Yale College, a tornado at Mayfield, O., August 1, 1842. Also a tornado at Stowe, O., October 20, 1837.

Prof. O. N. Stoddard, of Miami University, Ohio, a tornado at Brandon, O., January 20, 1854.

Prof. James Espy, a tornado at New Brunswick, N. J., June 19, 1835.

Prof. Brewer, of Yale College, in 1878.

Dr. J. H. Kain, of Tennessee, a tornado at Shelbyville, Tenn., June 14, 1830.

John Chappellsmith, of Indiana, a tornado at New Harmony, Ind., April 30, 1852.

Dr. Ezra Michener, of Toughkenamon, Pa., in 1877.

Prof. Richard Darlington, Jr., of Ercildoun, Pa., in 1877.

Prof. Farrar, of Cambridge, in 1815.

Prof. Wm. Blasius, Philadelphia, a tornado at West Cambridge, Mass., August 22, 1851.

Prof. Francis E. Nipher, of Washington University, St. Louis, a tornado at Collinsville, Ills., April 14, 1879.

Hon. T. H. Van Horn, Kansas City, Mo.

Prof. W. W. Daniels, of University of Wisconsin, the Wisconsin tornadoes of May 23, 1878.

Prof. Jno. H. Parker, Topeka, Kans.

Dr. Gustavus Hinrichs, of the University of Iowa, and Director of the Iowa State Weather Service.

Col. C. Shaler Smith, Chief Engineer of the St. Louis Bridge.

Silas Bent, St. Louis, Mo.

Judge Jameson, District Courts, Chicago, Ills.

Prof. M. W. Harrington, University of Michigan.

Prof. J. H. Macomber, State Agricultural College, Iowa.

Prof. Richard Mansill, Rock Island, Ills.

Prof. Elisha Gray, Chicago, Ills.

John A. Tice, St. Louis, Mo.

Prof. J. T. Lovewell, University of Kansas.

Prof. T. C. Mendenhall, Director of the Ohio State Weather Service.

Prof. W. D. Davis, Cambridge, Mass.

Prof. Wm. Ferrel, United States Coast and Geodetic Survey.

The work here represented, with few exceptions, was confined to brief descriptions and investigations of individual storms.

From Europe comes a large mass of literature on the subject of revolving storms, including tornadoes. Some of the more im-

portant writers on this subject may be mentioned as follows: Bohun, Blanford, Elliott, Meldrum, Scott, Piddington, Reid, Willson, DeChevrells, Becquerel, Faye, Peltier, Poey, Fourrelt, Martins, Bebber, Dove, Hirn, Köppen, Knipping, Reye, Oersted, Schück, Boscorich, Vines, Mohn, Celoria and Zantedeschi. Of all the names here mentioned, none gave the subject of tornadoes any special attention, except perhaps, Poey, Faye and Mohn.

It will now be opportune to consider, in brief, what the Signal Service has accomplished, by observation and investigation. We will now define what we mean by the word tornado, and how we shall distinguish this storm from others which are known to us and possessed of prominent characteristics.

THE TORNADO.

The general direction of movement of the tornado is invariably from a point in the southwest quadrant to a point in the northeast quadrant. The tornado cloud assumes the form of a funnel, the small end drawing near to, or resting upon, the earth. This cloud and the air beneath it revolve about a central vertical axis, with inconceivable rapidity, and always in a direction contrary to the movement of the hands of a watch. The destructive violence of the storm is sometimes confined to a path a few yards in width, as when the small, or tail-end, just touches the earth; while on the other hand, as the body of the cloud lowers, more of it rests upon the earth, the violence increases, and the path widens to the extreme limit of eighty rods. The tornado, with hardly an exception, occurs in the afternoon, just after the hottest part of the day. The hour of greatest frequency is between 3 and 4 P. M. Tornadoes very rarely, if ever, begin after 6 P. M. A tornado commencing about 5 P. M. may continue its characteristic violence until nearly 8 P. M., which means only that the tornado cloud may be travelling after 6 P. M., or after 7 P. M., but it does not develop; that is, make its appearance for the first time after those hours. Outside of the area of destruction, at times even along the immediate edge, the smallest objects often remain undisturbed, although at a few yards distant the largest and strongest buildings are crushed to pieces. At any point along the storm's path, where there is opportunity afforded the tornado cloud to display its power, the disposition of the débris presents unmistakable signs of

an action of the wind, such as might be called a rotation, from the right through the front to the left around the centre. The destructive power of the wind increases steadily from the circumference of the storm to its centre.

Observations with a single isolated barometer will not indicate the approach of a tornado, however near the position of the instrument to the path of the storm, but such observations are of value when a number are displayed upon the daily weather map.

THE CYCLONE.

This term was originally employed by Piddington to characterize the typhoon of the China Seas. As employed by the Signal Service, it applies to the broad, violent storms such as reach the South Atlantic and Florida coasts from the West Indies.

Cyclones have a varying width of path from 100 to 1,000 miles. Their course of progressive movement is a parabolic curve which trends northwestward from the West Indies, under the influence of the Northeast trades, and the general drift of the atmosphere until they reach the vicinity of parallel 30° N., when they slowly curve to the Northeast, continuing in that direction, either along the coast, or at a short distance inland. The storm finally disappears to the Eastward in the vicinity of parallel 50° N.

Within the storm area, the air does not actually move or whirl in a circle: there is only a tendency to such a movement about the region of lowest barometer.

Cyclones are otherwise characterized by sudden rapid and unusual oscillations of the barometer, heavy precipitation, heavy ocean swells and high straight wind velocities, which frequently exceed 100 miles per hour. The violence of the storm increases from the circumference towards the centre, reaching its maximum about midway between the centre and circumference of the storm. At the centre of the cyclone, nearly a dead calm prevails.

THE HURRICANE.

Although it seems hardly necessary to define the hurricane, it will, perhaps, be well to state that, as here considered, it means a straight wind of extraordinary velocity. They may, and frequently do, occur without the accompaniment of any precipitation. On the summit of Mount Washington, White Mountains, N. H., a measured velocity of nearly 200 miles per hour, has been

recorded. On the summit of Pike's Peak, Rocky Mountains, Col., a measured velocity has several times exceeded 100 miles per hour. On the coast of the Carolinas, maximum measured velocities have ranged from seventy-five to 160 miles per hour. In the Eastern Rocky Mountain slope, and in the lake region, measured velocities are sometimes recorded ranging between sixty and eighty miles per hour. This storm may be known as the Blizzard of the Northwest, the Chinook of the Northern Plateau, the Norther of the Southern Slope and Texas, or the Simoon of the Desert. Hurricanes may occur at any hour of the day or night, and in any month of the year. The most violent, however, take place during the spring and autumn. The width of the path of the storm is very irregular, and may vary from many rods to many miles. In either case, the velocity at all points within the storm's path is not necessarily the same; in fact, such a condition never occurs. The duration of the storm is also extremely variable; it may continue for only a few minutes or for several hours, although, in the latter case, the maximum velocity is not maintained throughout the entire period. On the contrary, there are periods of recurrence alternating with decided diminutions of the highest activity. There are, perhaps, but few portions of the country altogether free from the possibility of their occurrence. In the low table lands of mountainous regions, where most of the country is extremely broken, the habitable portions are shielded from the power of violent wind storms. No surface currents can attain any great velocity in such regions, although, on the mountain peaks and elevated plateaus, dangerous hurricanes at times prevail.

THE WHIRLWIND.

In defining this phenomenon it will be best perhaps that you should be asked to recall the occurrence, on any warm day, of the formation of a dust-whirl as it suddenly bursts upon you in the open street, fairly enveloping your body with fine particles of dirt, straw, leaves, and the like. Whirlwinds suddenly start up from some barren, sandy spot unduly exposed to the direct rays of the sun. Over a small surface thus exposed the air rapidly rarifies and ascensional currents form which move spirally inward and upward, carrying dust, leaves, straw and sometimes objects of considerable weight. The air within the whirl moves either from left to right

or in the contrary direction. The whirlwind's path has a diameter of several feet (sometimes rods) and the direction of its course of movement is decidedly irregular, possibly moving toward any point in the compass. On the sandy plains of Arizona, Southern California and Nevada these phenomena occur with great frequency during the summer months. Columns of whirling sand, sometimes several in a group, move rapidly over the surface. Whirlwinds are harmless and generally of but a few moments duration. In comparison with the tornado, let it be borne in mind that the former starts from the earth's surface, extending upward and moves onward, not leaving the earth, being solely confined to the region of surface currents. The tornado forms near the superior limit of the lower regions of the atmosphere and between the upper and lower sets of currents prevailing in the upper and lower regions of the atmosphere. The former currents are indicated by the appearance of the fine cirrus clouds and the latter by the heavy cumulous formation. From this lofty seat of origin, the tornado cloud gradually descends to the earth's surface, increasing rapidly in size and augmenting in power.

WATER-SPOUTS.

These disturbances generally form at a considerable height in the air, although at times they seem to ascend from the water's surface; that is to say, there is no visible agent influencing the ascension of the water, but, of course, in every instance the causative power is from above, and in the latter case, near the water's surface. When I speak of the formation of the water-spout at a considerable height in the air, I mean that the embodiment of the whirl, or the revolving current of air, first appears as a dark cloud of minutely divided particles of water, the result of rapid condensation, of course in the air, and, therefore, above the water. The swift passage of the air in a spirally, upward motion over the surface of the water raises it in the form of spray and carries it upward in the centre of the whirling cloud, which then presents the appearance of a densely opaque body, and conveys an impression to the eye of the observer that a huge column of water is ascending in the form of a long spout, widening gradually toward the top. There are instances, however, where the force manifested was sufficient to raise a considerable quantity of water several hundred

feet in the air. Water-spouts form during periods of excessive heat, generally in the afternoon, and at or near the hottest part of the day. In the temperate zone, they only occur during summer months.

They are of most frequent occurrence in the region of calms between the Tropics, but are not altogether strange sights in the Gulf of Mexico and along the Gulf stream, south of parallel 40° N. In regard to motions, they possess both a rotary and progressive action, but in neither do they manifest a permanency of direction. Water-spouts cannot be considered as altogether harmless, for there are instances where vessels have been wrecked by them.

HAIL STORMS

Are peculiar atmospheric disturbances, which, in regard to the dimensions of their paths, are, next to the tornado, the most circumscribed of all storms, save the whirlwind. They are characterized by a strange cloud formation and a peculiarity of precipitation unlike any other phenomena in the category of storms. The cloud from which the hail falls is basket-shaped, with a dark and portentous exterior, a ragged and ominous-looking opening at the bottom, and within, a whirling conglomeration of snowflakes, pellets of snow and ice, partly formed hailstones, the latter of an almost infinite variety of shapes The hail cloud forms between the currents of the upper and lower regions of the atmosphere, and moves forward in the plane of these currents, either within or just above the upper limit of the lower atmospheric regions, where it finally disappears and the deposition of hail ceases. The path of the storm as indicated by the distribution of the hailstones, is, at times, very narrow, although the range of width is decidedly inconstant, varying from one to fifteen miles. The hail storm travels quite rapidly, from thirty to fifty miles per hour, and the length of its path is even more variable than the diameter, ranging as it does from ten miles to two or more hundred. The direction of the course pursued by the storm is always from some point West to some point East. It may be from Northwest to Southeast, or from Southwest to Northeast. Hail storms may occur at any time of the day or night, although they are most frequent in the afternoon, just after or near the hottest part of the day.

They are most prevalent in that region of country embraced

between the parallels of 30° and 50° N. South of parallel 30° N. hail storms are of rare occurrence at the level of the sea, but at the height of 100 or 200 feet they occur more frequently, and in the mountains of British India they are very common, the hailstones being usually of large size. Hail storms are not necessarily confined to the land areas, but may and frequently do occur over large and small bodies of water.

THUNDER STORMS.

These phenomena are atmospheric disturbances of great variability of extent and power. They are invariably accompanied by such manifestations of the presence of electricity as are ordinarily termed thunder and lightning, the former being entirely consequent upon the existence of the latter. Thunder is but the reverberations of the concussion produced by the inconceivably rapid propulsion through the air of that physical element we are pleased to term electricity. Thunder storms may be a few miles or several hundred in extent, and their length of duration is quite as uncertain, viz.: From a few hours to one or more days. There is no regular time of day for their occurrence, although they are, perhaps, more frequent in the afternoon. However, they may occur at any time during the day or night. As to the season of year, summer is the period of greatest prevalency. There is no month of the year entirely free from them. Whether the precipitation be rain or snow, the presence of electricity has still been manifested in the usual form. With the former character of condensation of vapor, the evidence of electricity is most common, while with the latter it is the rare exception. A valuable paper on this class of storms has lately been published by Prof. Hazen, of the Signal Service.

As regards geographical distribution, thunder storms are most frequent between the equator and parallel 40° N., and from thence to parallel 70° N., the average frequency diminishes with considerable rapidity. In the vicinity of parallel 80° N. it is believed they never occur, although this in the main is mere supposition. There are certain portions of the United States where thunder storms are unusually frequent as compared with other parts. They seldom occur in the Pacific Coast States, especially California, and are most frequent and violent in the Eastern Rocky Mountain Slope, the lower Missouri Valley and in the Lake Region.

Having briefly outlined the characteristics of the various classes of storms well known to the United States, we will now proceed to consider the subject of our paper—the dreaded tornado. Right at this point I must refrain from entering too largely into interesting details for fear of making this paper too prolix. At this stage of our inquiry in regard to the character and classes of storms, I presume it will be admitted, that no two of the several storms defined, at least *appear* to be alike. There are, however, points of resemblance and in some, these features are stronger than in others. As each is studied more carefully, the essential points of difference, if any, will be more clearly contrasted. It is not within the province of this paper to discuss at *length* the points of difference or harmony, nor enter into an intricate analysis of meteorological phenomena and the multiform operations of atmospheric changes attending the origin, development and complete formation of these disturbances.

Let us examine into the methods of investigation pursued by the Signal Service and trace the progressive development. It was first necessary to gather the facts. This required field-work and the careful examination of the entire track of a tornado. At first this individual investigation was faulty in that it lacked system, and a thorough knowledge of what was wanted. The tendency in isolated investigations was to seek the sensational features of the occurrence and ignore the methods leading to the discovery of important truths. Thorough field-work produced its rewards. Aided by the records of past tornadoes embracing descriptions more or less complete, the investigator was enabled to classify the data within reach and watch for coincidences and relations which paved the way for conclusions, which provided the means of arranging a more systematic method of conducting individual investigations.

Field-work was continued by a representative of the Signal Corps until it was found that the burden was too great for one man, and the results were not commensurate with the expenditures. Field-work, however, must continue, but another plan was necessary to make it effective. Out of this necessity grew the present large and efficient corps of Tornado Reporters for the Signal Service, numbering about 1,500 all told.

The establishment of this special corps of observers became

necessary in order to gather the exact information desired with the least possible delay. The largest number of stations are necessarily located in those States in which tornadoes are of the most frequent occurrence. The peculiar geographical distribution of tornadoes necessarily limits our study to certain States that are frequently visited, and other portions seldom, if ever, visited by tornadoes. In the regions of greatest frequency the stations number from two to four in each county, depending upon its area. Tornado reporters, in return for their voluntary contributions, are supplied with the tornado publications of the Signal Service; they are also furnished with instructions and materials necessary for the taking, recording and mailing of observations and reports. Reports are forwarded to the Chief Signal Officer as soon as possible after the occurrence of a tornado, and consist of detailed descriptions, instrumental observations, photographs, diagrams, charts, and illustrations. While attention is principally given to the examination and report of tornadoes for the current year, each tornado reporter is instructed to work up the past history of these storms in his State, making careful search after any facts relating to windfalls, or other traces of past tornadoes.

Some of the results sought to be obtained by the above method of investigation may be briefly given as follows:

(1.) To determine the origin of tornadoes and their relation to other atmospheric phenomena.

(2.) To determine the geographical distribution of tornadoes and their relative frequency of occurrence in different States, and in different parts of the same States.

(3.) To determine the conditions of formation with a view to the prediction of tornadoes.

(4.) To determine the means of protection for life and property.

(5.) To determine the periodicity of the occurrence of tornadoes and their relative frequency by seasons, months, parts of a month, and time of day.

(6.) To determine the prevailing characteristics of tornadoes.

(7.) To determine the relation of tornado regions to areas of barometric minimum.

(8.) To ascertain yearly the loss of life and property in the various tornado districts and its effect upon the industries of the people.

(9.) To ascertain the influence of topography upon the occurrence and movement of tornadoes.

(10.) To determine the influence of rainfall and forests upon the development of tornadoes.

(11.) To ascertain the relations of tornadoes to hail storms, thunder storms, and hurricanes.

While the inductive stage of the work is receiving earnest and unabated attention, the deductive demands and receives as much consideration as limited means will permit. More is demanded in this direction than the means at hand will provide for. It cannot be wondered at that the public are clamorous for results, yet, if the scope of their charity was only measured by the extent and variety of their demands upon the Service, ventures could be made and results arrived at that otherwise remain in the dark until the methods by which they are obtained have been tried in the furnace of fire, hung up to cool and then tested again. However, it pays to summer and winter every important deduction before you declare its truth to the world.

We have now hunted the tornado in its lair, we have elaborately sketched and worked out its details of horror, devastation, singular characteristics, mighty force and many of its peculiar mysteries.

What can we hope for as the result of this work, this acquisition of knowledge in details? Some have said: Study one tornado thoroughly and you have exhausted the subject. But this is a narrow and hopeless view of the situation. It is a weak confession that difficulties cannot be successfully encountered. Had we stopped at this point some years ago, the possibilities of prediction would have remained a myth, and many important truths sealed among the clouds. Persistent labor has opened a portion of the winding pathway and revealed some of the hidden secrets, preparing the way for others of still greater intricacy. Still the question is asked, what can we do with the tornado? it comes and goes with the lightning's flash and strews its pathway with the horrors of death and desolation. Many plans have been devised and submitted, but never tested, to destroy the violence of a tornado. The author, or inventors, in most cases lacked confidence in their own handiwork, while in other instances the scheme was so uncertain and of such magnitude that a government must supply the means for experiment, and efforts to obtain such assistance has always proved unsuccessful.

We have not entered as a competitor in this field. After a careful survey of the possibilities, such as they appeared at the time, it was considered impracticable to employ any means to destroy the tornado cloud, or to adopt any line of work involving destruction of cloud, or preventation of formation.

We have taken the tornado as it is, admitting certain things, contesting others, looking at it as a scientific problem with two sides: one practical, the other abstract and purely scientific. The questions involved in both are extremely important and require for their elucidation the most patient and laborious methods of investigation. In any event, our work must show a determined effort to be beneficial, with reasonable assurance that such efforts will prove successful. In what direction can such results be accomplished? The answer is, in the forecasting of conditions favorable for the development of tornadoes. This is, at present, the great desideratum from both a practical and scientific standpoint. Tornado prediction involves the most intricate study of atmospheric phenomena. The successful prediction of a tornado will not of itself prevent the destruction of buildings, crops and machinery, but it will give opportunity for preparation to protect such property, and more than all that, it will provide against the destruction of life, and much personal property, the latter in the shape of valuables, that are readily moved from place to place. Not least among the advantages to accrue from forecasting is the relief from undue excitement, and anxiety in those sections of country where the tornado is of frequent occurrence. A person who has not witnessed the feeling prevailing at such places during the tornado season, can have no conception of its direful influence and depressing effect. The approach of every black cloud on the horizon, or the sudden freshening of the wind are danger signals to the majority of the people, and consternation prevails at once. Factories and shops close, and business is paralyzed for the day. This great loss to mind, body and estate is repeated many times during the tornado season, when there is really not the least sign of a tornado. But only the eye of the student of the weather map can detect the lurking indications of tornado development.

By admitting the exclusiveness of map study, I do not mean to deny that there are important atmospheric conditions which the isolated observer may carefully watch and study with profit, as for

example: the gradual setting in and prolonged movement of the air from the north and south points; the gradual, but continued fall of the thermometer during the prevalence of the former currents, and a rise during the predominance of the latter.

If the northerly currents are the prevailing air movements at the place of observation, the atmospheric disturbance is forming southward, but, if the prevailing currents are from the South, then to the northward of the observer.

Carefully study cloud development, color as well as form; also, manner and direction of approach. Clouds render visible the air currents, and are full of meaning. A study of the currents of the atmosphere would be impossible without their existence, and that, too, in a variety of forms. Dispense with cloud formation, and the face of the sky would become blank, and severe storms no longer visible.

Wind direction, temperature, and clouds, are proper subjects of observation and investigation by the isolated observer. The barometer is of less importance in this line of inquiry, unless the barometric observations can be promptly compared with those taken at other points near by and at the same moment of time. The tornado itself is an extremely local affair, and the accompanying barometer changes do not affect a large extent of country. Probably if a barometer were placed in the immediate track of the tornado cloud, it would not, with any certainty, indicate the presence of the storm until the crashing winds had fallen upon the instrument.

Having asserted and briefly shown that tornado prognostications may be valuable and beneficial, the question is asked can they be successfully made? The reply is in the affirmative. There are, however, several difficulties to be encountered, not incident to the preparation of general weather predictions.

The following are most of the features of map study that must receive consideration in the preparation of a tornado prediction for any day.

(1.) Barometric Trough. Region. Ratio of Axes. Pressure. Departure from Normal.

(2.) Central Area of Barometric Minimum. Region. Pressure. Departure from Normal.

(3.) High Contrasts of Temperature. Region. Gradient.

(4.) High Contrasts of Cold Northerly and Warm Southerly Winds. Region.

(5.) High Contrasts of Dew-point. Region. Gradient.
(6.) Heaviest Lower Cloud Formation. Region. Kind.
(7.) Opposing Movement of Lower Clouds. Region. Directions.
(8.) Coincident Movement of Upper and Lower Clouds. Region. Direction.
(9.) Opposing Movement of Upper and Lower Clouds. Region. Direction.
(10.) Opposing Movement of Lower Clouds and Winds. Region. Direction.

I cannot lead you through the details of this work within the scope of this paper. Sufficient to say that the work affords gratifying results as will be shown.

Tornado prediction is no longer a possibility, but in many respects may be considered an accomplished fact. By this I do not mean absolute perfection, but reasonable success. The system of preparation and study which leads to the result is subject to improvement, both as to manipulation of charted data and the verification of forecasts. It is believed that the work now in hand, with the above end in view, will greatly advance the present measure of success.

Beginning with the year 1884, the daily weather maps were closely studied to determine the conditions favorable for the development of tornadoes. On the tenth of March, 1884, regular tornado predictions were commenced experimentally, and during the remainder of the month were made twice daily at intervals of eight hours. The first prediction was made from the morning (7 A. M. Washington time) weather map and embraced the eight hours up to 3 P. M. The second prediction was made from the afternoon (3 P. M. Washington time) weather map, and embraced the eight hours up to 11 P. M.

For the month of April, the same plan was followed.

For the month of May, June and July only one prediction daily was made. This prediction resulted from a study of the 7 A. M. (Washington time) weather map and embraced the sixteen hours up to 11 P.M. Tornado predictions were made for certain districts. That portion of the United States lying between the seventy-seventh and 102d meridians was divided into eighteen sections or districts. Tornado predictions for the year 1885 began June 1st and terminated September 20th. These predictions were made from a study of the 7 A. M. (Washington time) weather map and embraced the sixteen hours up to 11 P. M.

In preparing for the work of making tornado predictions, it was

necessary to ascertain as nearly as possible the limits of that portion of the United States within which tornadoes were most likely to occur. These limits were determined from the geographical distribution of tornadoes, as taken from the records of the past ninety years. Each district was subdivided by imaginary lines into four equal parts, and predictions were made either for the entire district, or for any one, or more, of these parts. As a whole, this study proved fairly successful for the period during which the work progressed. In no instance where it was predicted that conditions were favorable for the development of tornadoes did violent storms fail to occur, either hail, hurricanes, or tornadoes. But no prediction was considered entirely successful unless the characteristic funnel-shaped cloud was actually reported as a feature of the storm, and that the tornado's path was clearly within the region, or district, for which the prediction was made, and that the tornado occurred within the eight or sixteen hours specified in the prediction. All of the most remarkable and destructive tornadoes of the two seasons were predicted for the districts within which they occurred from five to eight hours in advance of their appearance. It was not considered advisable to furnish these predictions to the public at the time they were made, because the work was undertaken experimentally, as a matter of study and official record, with a view of ascertaining what might be accomplished in this direction for the benefit of the agricultural sections of the country.

In what follows there is presented in concise form some of the most important results that have been attained by the methods of investigation already pursued:

(1.) That there is a definite portion of an area of low pressure within which the conditions for the development of tornadoes is most favorable, and this has been called the dangerous octant.

(2.) That there is a definite relation between the position of tornado regions and the region of high contrasts in temperature, the former lying to the south and east.

(3.) That there is a similar definite relation of position of tornado regions and the region of high contrasts in dew-point, the former being, as before, to the south and east.

(4.) That the position of tornado regions is to the south and east of the region of high contrasts of cool northerly and warm southerly winds—a rule that seems to follow from the preceding,

and is of use when observations of temperature and dew-point are not accessible.

(5.) The relation of tornado regions to the movement of upper and lower clouds has been studied and good results are still hoped for.

(6.) The study of the relation of tornado regions to the form of barometric depressions seems to show that tornadoes are more frequent when the major axis of the barometric troughs trends north and south, or northeast and southwest, than when it trends east and west.

(7.) The general direction of movement of the tornado is invariably from a point in the southwest quadrant to a point in the northeast quadrant.

(8.) The tornado cloud assumes the form of a funnel, the small end drawing near, or resting upon the earth.

(9.) The cloud and the air beneath it revolve about a central vertical axis with inconceivable rapidity, and always in a direction contrary to the movement of the hands of a clock.

(10.) The destructive violence of a tornado is sometimes confined to a path a few yards in width, or it may widen to the extreme limit of eighty rods.

(11.) The tornado, with hardly an exception, occurs in the afternoon, just after the hottest part of the day.

(12.) The hour of greatest frequency is between 3 and 4 P. M.

(13.) The destructive power of the wind increases steadily from the circumference of the storm to its centre.

(14.) Observations with a single isolated barometer will not indicate the approach of a tornado, however near the position of the instrument to the path of the storm, but such observations are of value in this connection only when a number of them are displayed upon the daily weather map.

(15.) The tornado season is embraced between the first of April and the first of October. There are, however, instances in a long series of years where tornadoes have been reported in every month of the year.

(16.) The months of greatest frequency are June and July.

(17.) Taking the whole United States together, it is found that the region of greatest frequency per year per square mile embraces the following States: Georgia, South Carolina, Illinois, Indiana, Iowa, Kansas, Missouri, Ohio and Wisconsin.

(18.) The movements of a tornado cloud are comprised within limits of four peculiar and distinct motions. Knowing these and obeying the rules given in Signal Service Notes No. XII as to his movements on the approach of a tornado cloud, no person need suffer injury or death from the fury of the storm.

(19.) No buildings however strong have yet been able to withstand the violence of a tornado.

(20.) People must resort to dug-outs and cellar caves, the preparation and use of which is indicated in Signal Service Notes No. XII, in order to place themselves and their valuables beyond the possibility of danger.

(21.) Under no circumstances, whether in a building or a cellar, take position in a northeast room, in a northeast corner, in an east room, or against an east wall, remembering that the tornado cloud invariably moves in a northeasterly direction.

(22.) The concomitants of the tornado are: An oppressive condition of the air, the gradual setting in and prolonged opposition of northerly and southerly currents over a considerable area, a gradual but continual fall of the thermometer, with a prevalence of the northerly currents, and a rise with the predominance of the southerly. Decided contrasts of temperature north and south of the line of progressive movement. Huge masses of dark and portentous clouds in the northwest and southwest, possessing a remarkable intensity of color, usually a deep green. A remarkable rolling and tumbling of the clouds, scuds darting from all points of the compass toward a common centre. Hail and rain accompanying the tornado, the former either in unusual size, form or quantity, and the latter either remarkable in quantity or size of drops. The presence of ozone in the wake of the tornado. A remarkable roaring noise, like the passage of many railroad trains through a tunnel. The clouds generated by the vortex assume the form of a funnel, with the smallest end toward the earth. The remarkable contraction of the storm's path; the remarkable definiteness of the limits of the storm's path. Upon reaching the earth's surface, the vortex assumes the form of an hour-glass. The vortex has four motions, viz: (1.) The whirling or gyratory motion, always from right to left; (2.) The progressive motion, generally from some point in the southwest quadrant to some point in the northeast quadrant; (3) The ricochet motion; (4.) The oscillatory motion.

(23.) The characteristic effects of a tornado are: Objects are drawn towards the vortex from every point of the compass. Objects passing into the vortex are thrown upward and outward by the vortical action of the engaged air. Structures are literally torn to pieces by the vortical action of the air, evidence of which is afforded both by the fineness of the débris, and also its disposition in the storm's path. The débris is thrown inward from each side of the storm's path. Light objects are carried to great heights, and also to great distances. Objects are carried inward and upward by the centripetal and outward by the centrifugal force of the vortex. Weight or size are conditions which generally present immaterial values to the power of the tornado. Persons are stripped of clothing. Fowls and birds are denuded of feathers and killed. Trees are whipped to bare poles. Long and heavy timbers are driven to considerable depths in the solid earth. The vortex is completely filled with flying débris. Timbers are driven through the sides of buildings. Sand and gravel are driven into wood. Human beings and animals are run through with splinters and timbers. Straws, bits of glass, and pieces of metal are driven into wood. The strongest trees are uprooted or twisted off near the roots. Men and animals are terribly mangled by contact with flying débris, and by being rolled over the ground for considerable distances. In the path of the storm all vegetation is destroyed. Railroad trains are thrown from the track. Iron bridges are completely dismantled and carried from their foundations. Heavy bowlders, weighing tons, are rolled along the earth. The largest railroad engines are lifted from the tracks on which they rest. All objects, whether metal or non-metallic, magnetic or non-magnetic, simple or compound, animate or inanimate, are acted upon in a similar manner.

(24.) Cheap buildings, dug-outs and cellar caves, with general insurance, is recommended as the wisest policy to be pursued by people living in the tornado districts. During the past four years tornado insurance companies have been formed, and tornado risks have been written by several large companies engaged in other branches of insurance. Within the period above indicated tornado risks have been taken to the amount of about $50,000,000 in the tornado districts of the country, principally in the West. The terrible loss of life and property which follows in the wake of a

tornado, and the intense suffering and misery endured by those who survive its perils, only to find that all their worldly goods have been swept away, makes this storm one of the direst calamities that can befall a community. Hundreds of thousands of dollars' worth of property are destroyed in a few hours and scores of persons killed, or maimed for life, along the track of a single tornado.

The study of the origin, nature and the laws governing the development and movements of this class of local storms is of the utmost interest to the agricultural sections of the tornado districts. The work already accomplished has been received with great satisfaction by the people living in the regions traversed by these storms. During the year, numerous letters have been received from nearly every State in the Union, testifying to the progress and success of the work.

Another evidence of the importance and success of the work is that illustrated by the existence of a large corps of voluntary observers, and the enthusiasm manifested by them in the work upon which they are engaged. In many instances tornado reporters have made unusual efforts to obtain exact information concerning the peculiarities of a storm, and in some cases have fitted out at their own expense surveying parties, for the purpose of carefully and accurately investigating the entire track of a single tornado, extending, maybe, a distance of from thirty to 100 miles. All of this information is received by the Chief Signal Officer in Washington, without other expense to the Government than the cost of blank forms, envelopes, wrappers and printed instructions. The data thus collected during each tornado season are carefully studied and prepared for publication with the view of placing it before the people of the tornado districts in the most practicable form and with the least possible delay. The published results of each year's work should reach these people before the opening of the next tornado season, if possible, for the information contained therein may prove of great benefit to guard against the dangers of another season. But present appropriations do not provide the necessary means.

The information above referred to does not include that to be obtained through the medium of tornado predictions, which, if made, should be furnished to the public each day through the

agency of the telegraph. More can be realized from the work of tornado predictions when we have established a normal average of occurrence for each tornado district. This normal will be founded upon the results obtained from a very faithful record of the entire region embraced, for a chronological period of at least twenty-five years. I am now engaged upon this work, and hope that by the opening of the tornado season of 1886 I shall have the necessary data completely available.

In the study of tornadoes it has become necessary to undertake something more than a simple record of their occurrence or an occasional investigation of those that are attended with unusual destruction to life and property. A practical knowledge of the nature of these storms is a matter of the utmost interest to the inhabitants of the tornado districts; and not least among the objects aimed at by the Chief Signal Officer in directing the continuance of tornado investigations is to allay any needless anxiety or fear on the part of those people living in the regions most frequented by tornadoes. Methods of observations based on reports from stations situated from 100 to 200 miles apart, as in the case of cyclones and hurricanes, are inadequate to develop the mysteries of the funnel-shaped cloud.

BREAD FERMENTATION.—Aimé Girard communicates to the French Academy the result of experiments undertaken to show whether the rising of bread is due to a spirituous fermentation, or whether that hypothesis should be rejected, as some eminent savants now think. In some of the experiments, yeast was employed, in others leaven. The amount of gas and the relative proportions of carbonic acid, oxygen and nitrogen were carefully noted, as well as the quanity of alcohol produced. The results represent, as exactly as one could wish, the requirements of Pasteur's equation of alcoholic fermentation.—*Comptes Rendus, Sept. 14, 1885.*

REPORT ON METEORIC DUST.—Experiments have been made at the Scottish Marine Station, by means of an apparatus in which the wind blows through gratings of fine platinum wire. The moisture deposited is collected and examined for suspended particles. Funnels have also been placed at different localities for catching rain. Carbonaceous matter is most common. In smaller quantities occur quartz, feldspar, mica, turmaline, garnet, volcanic dust or pumice and round magnetic particles, about $\frac{1}{5000}$ of an inch in diameter. They resemble similar larger particles from deep-sea deposits at the greatest distance from continental land. None are of cosmic origin. Usually they have a small nucleus in the interior, but they are frequently hollow. Further observations are to be made at various stations, all over the world.—*Nature, Oct. 1, 1885.*

RAPID TRANSIT AND ELEVATED RAILROADS, WITH A DESCRIPTION OF THE MEIGS ELEVATED RAILWAY SYSTEM.*

By Francis E. Galloupe, M. E., Boston, Mass.

[*Concluded from Volume CXXI, page 220.*]

DISCUSSION.

Mr. Durfee.—I would like to ask the author of the paper a question that occurred to me while he was reading it—whether those diagonal wheels are sustaining wheels or steadying wheels. The exterior diameter of the wheel is considerably larger than the diameter of the bottom of its groove, and, it seems to me, there must be a grinding action there.

Mr. Galloupe.—The diagonal wheels are the sustaining or supporting wheels for the weight. We do not suppose that that grinding action will be any worse than the present flange friction upon the ordinary wheel; but it can be entirely prevented by using the ordinary form of rail placed at the proper angle and changing the shape of the wheels to wheels having a flat tread with or without flanges at the sides.

Mr. Durfee.—It seems to me that the grinding action there must be very destructive both to wheel and track. It would bring a very awkward strain on the inner flange of each wheel.

Mr. Kent.—I did not notice any suggestion in the paper regarding the influence of wind strains. We know how the Tay Bridge fell down, because it did not have a wide enough base.

Mr. Galloupe.—All these questions have been carefully considered and gone over. It has been studied for some five or six years both by civil engineers as well as mechanical engineers, and strain sheets made with every modification of the track structure, and besides the calculations of theory, tests by model were made so far as practicable. The whole system is now being built of full size, experimentally, with about one-half a mile of track containing the most extreme conditions as to grades and curves

*A paper read at the Boston meeting, 1884, of the Amer. Soc. Mechanical Engineers, and reprinted from advance sheets of the *Transactions*.

and difficulties, which will ever be likely to occur in practice, and it is to be tested practically to see whether the theories will be upheld. All these things have been considered, and the maximum strains that can be brought on the way and on every part of the system have been taken in designing it.

MR. HALSEY.—I am not a railroad man, but I see one point in the design which appears to be very objectionable—the switch shown on page 147. In principle this is substantially the old-fashioned stub switch, the dangers of which are so great, even on surface lines of track, that in the State of New York I believe its

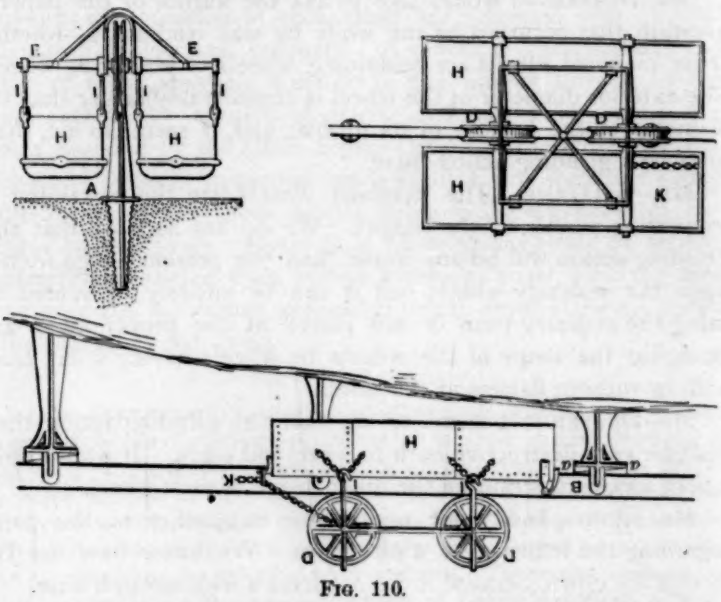


FIG. 110.

use is now prohibited by law. It does not seem possible with a track constructed on this plan to apply any of the modern safety switches. As the result of a misplaced switch of the construction shown, might be to run a train off the end of the track and drop it bodily into the street, the objection seems to me a serious—perhaps a fatal—one.

MR. DURFEE.—The idea of supporting a train of moving cars upon a single rail supported by girders sustained by posts, is a very old one indeed. In the year 1824, five years before the opening of the Liverpool and Manchester Railway, Henry R. Palmer,

civil engineer, published a "Description of a Railway on a New Principle,"* which consisted of a single track supported on posts. The wheels and trucks were above the roof of the cars, which were suspended from the trucks like panniers, on each side of the track (*Fig. 110*). The centre of gravity in that construction was very much lower than in the one under consideration. One of the illustrations of Mr. Palmer's book (reproduced in *Fig. 111*) is of especial interest, as showing an early form of the cantilever bridge. The form of single rail, post-supported track described by Mr. Palmer, has been several times before the public since the publication of his book. In the year 1834, Henry Sargent, of Boston, built at Chelsea a circular railway (intended for amusement only) on this plan, and commenced the construc-

FIG. 111.

* Description of a railway on a new principle, with observations on those hitherto constructed, and a table showing the comparative amount of resistance on several now in use. Also an illustration of a newly-observed fact relating to the friction of axles, and a description of an improved dynamometer for ascertaining the resistance of floating vessels and carriages moving on roads and railways. By Henry R. Palmer, Civil Engineer, Member of the Institution of Civil Engineers. With plates. Second edition, revised. London: Printed for J. Taylor, at the Architectural Library, High Holborn, 1824.

tion of a larger structure in East Boston, on a location described as "a marshy piece of ground, full of creeks and ponds, and much more unfavorable than the average surface of the country." At the Centennial Exposition, there was a short section of single rail on posts, on which ran a peculiar locomotive, having a passenger car attached Other examples of similar attempts might be given. I fail to detect any conspicuous novelty in the car body described; substantially the

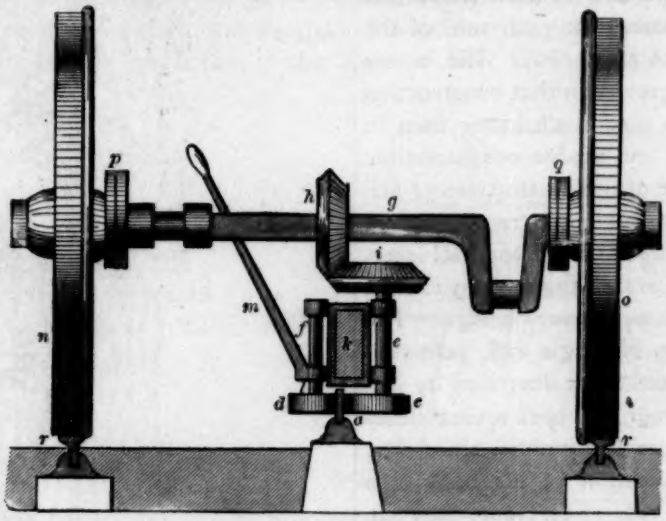


FIG. 112.

same construction was proposed by a Mr. Robbins, and an illustrated description thereof published many years since. The plan proposed to insure tractive power by means of a pair of horizontal gripping wheels, was originally devised by Vignoles and Ericsson (*Fig. 112*), and an English patent granted therefor in 1830, and it has been patented several times since both in England and the United States. It was used on the Mont Cenis Railway, but was not regarded as a decided success.

PROF. HUTTON.—There is one thing to which I look forward with interest, and that is to see how they will manage one of the details of the switch. If it is desirable to have the switch move over a very small angle it would seem as if it were necessary that a very long girder should be used to be swung at its heel in order that the permanent way of the siding may clear the permanent way

of the main track. I know that that has been one very great difficulty in railways constructed on this principle heretofore.

MR. SCHUHMANN.—During the Centennial Exhibition there was shown a short elevated railroad, and that had the rail in the middle and the wheels on top of the car. The car itself hung down, saddle fashion, on both sides of the rail, as in the form illustrated by Mr. Durfee.

THE PRESIDENT.—Was the power contained within the car?

MR. SCHUHMANN.—I believe it was; I do not remember exactly. The road was only about 150 feet long. They used to take passengers on it for five cents. It ran across Lansdowne Ravine in Fairmount Park.

ADDED SINCE THE MEETING.

MR. GALLOUPE.—In answer to Mr. Durfee's remark that a slipping or grinding action of the truck wheels would bring a strain upon the inner flanges of the wheels, I would say that it was particularly intended to show in the paper, under the discussion of the truck's action, that such a thing could not occur, as demonstrated both by theory and actual trials with models. The stresses must de distributed on both flanges or sides of the truck wheels equally, or they will move upon their axles (since there is nothing to resist motion in contact with the hubs, and the position of the wheels is entirely governed by the rails) until this occurs. This has always been found a difficult point to establish, but will I think become clear upon a little reflection. It is one of those cases where seeing, rather than trusting to theory, is believing.

In regard to Mr. Halsey's comment upon the switch, I would say that it is difficult to judge of a thing involving so many new conditions by the analogies of the surface railroads. We have here no very small rail section or switch points, invisible to the engine driver beyond a few feet away, and hence necessary to have the protection of a safety frog, but in this case a large girder 2 feet wide by 4 feet in depth comprising the switch section, its position being easily seen for a much greater distance, and hence largely increasing instead of diminishing the safety of this feature. Besides that, while the ordinary switch points have to be moved not more than an inch or two out of place to derail a train this switch may be moved *fifteen* inches out of place with no effect

resulting from a train running upon it in this position except to close it, an action following from the form and inclination of the truck wheels striking it.

The present safety switch system in use on surface railroads embodies the features of a continuous bearing for the supporting wheels, and this is by no means impossible in the Meigs system. It would involve the use of a girder of double the usual depth, and divided into two parts horizontally. The supporting wheels would run on the upper boom of the lower member, and this would be continuous except that it would have frogs. The upper member would be the one to be swung to connect the branch tracks and main line. The details of this safety switch have been worked out so far as to demonstrate that it is fully feasible, but in particulars, will depend largely in any instance on the details of girder selected, and on the maximum and minimum headway required or allowed by local authorities beneath the girder.

There is also a device to be soon applied to it that will hold the switch in one position or the other, as by springs, either open or closed, so that I do not see that the switch is more unsafe than the ordinary one, but quite the contrary. The great desideratum is to prevent derailment, a thing which the ordinary switch is not too perfect in accomplishing.

Prof. Hutton's suggestion that a small switch angle would necessitate a very long girder for the switch is undoubtedly true, but this truck will never require an inclination of switch section to main line greater than about 5°, and is moreover perfectly adapted to turning angles, not requiring a small switch angle, on account of its independently rotating supporting wheels, and the central position of the upper wheels about which the truck turns. With the above inclination, the length of switch truss will be moderate, not exceeding thirty-five feet.

As to the Robbins car, the only feature in common with it and the Meigs is that it is round, the method and weight of the framing and construction being dissimilar throughout. I believe they were both designed about the same time.

I am obliged to Mr. Durfee for alluding to the history of elevated or post-line railroads. The earliest proposer of a single post line railway, of which I know, in England is Henry Robinson Palmer, whose patent is dated November 22, 1821. He shows a

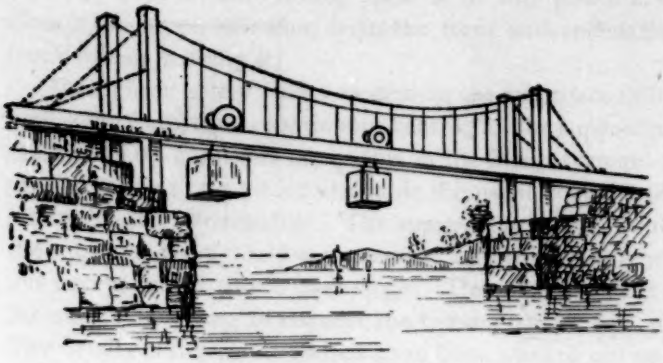


FIG. 140.- Fisher, 1825.

FIG. 141.—Newton, 1845.

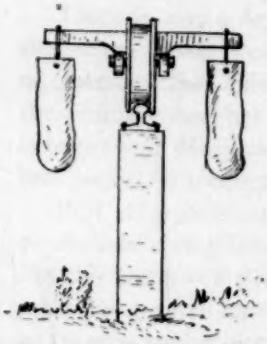


FIG. 139.—Palmer, 1821.

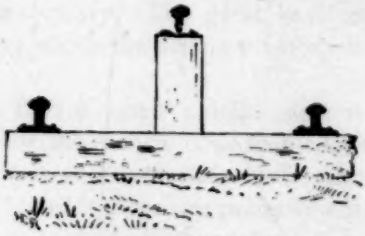


FIG. 142.—Clinton, 1846.

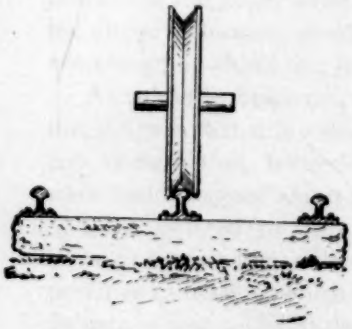


FIG. 143.—Brown, 1846.

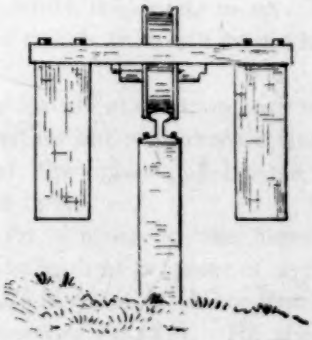


FIG. 144.—Sargeant, 1825.

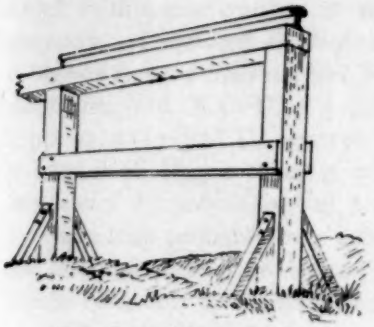


FIG. 145.—Stimpson, 1830.

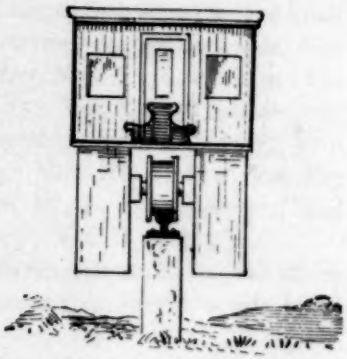


FIG. 146.—Bryant and Hyett, 1831.

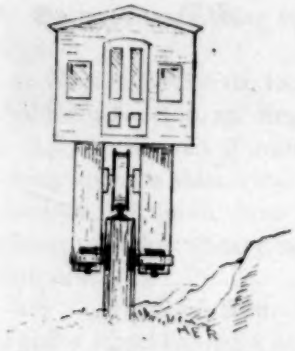


FIG. 147.—Emmons, 1837.

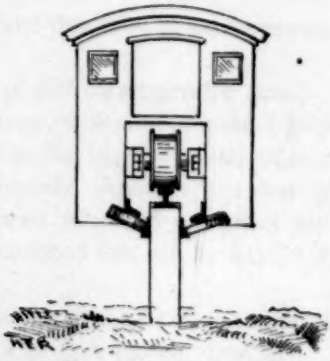


FIG. 148.—Crew, 1872.

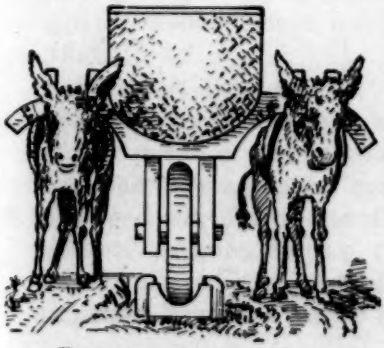


FIG. 149.—Cameron, 1878.

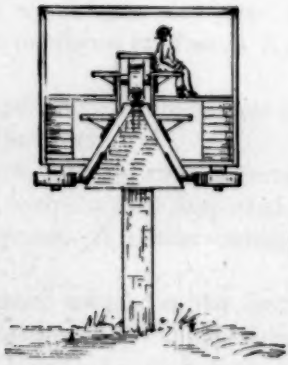


FIG. 150.—Stone, 1876.

beam carrying a single rail on top and supported upon a line of posts. Upon this rail runs a vertical supporting wheel for the load, which in this case consists of bags carried one on each side, like panniers. (Described in *Rep. of Arts*, Vol. I, 3d series, p. 129; *Newton's London Journal*, Vol. V, p. 151, Vol. X, p. 32: *Mechanics' Magazine*, Vol. XXVII, p. 349; *Register Arts and Sciences*, Vol. I, pp. 97, 131; Vol. II, pp. 150, 353; Vol. III, p. 141; Vol. IV, p. 219; Vol. I, new series, p. 9; Vol. IV, p. 25; *Engineers' and Mechanics' Encyclopædia*, Vol. I, p. 615; Vol. II, p. 425.]

Since then probably over 100 different patents have been taken out in England and the United States in this line, of which I will briefly refer only to the following:

Among the English patents, April 2, 1825, a patent was taken out by Jacob Jedden Fisher for a suspended railway, in which weights were shown suspended below the level of the rail on each side, the track itself being supported like the floor of a suspension bridge.

D. Maxwell, May 10, 1829, had a patent on suspended cars.

William Newton, an English attorney, took out a patent July 30, 1845, upon a rail of ordinary section, having horizontal wheels running upon its sides, close to the ground. Another was that of Robertson J. Clinton, June 4, 1846, who provided a central rail between the two ordinary rails, and elevated this rail to a higher position.

July 14, 1846, Sir Samuel Brown took out a patent on a central rail and a wheel having a notched or V groove to run upon it.

In the United States, we have Henry Sargeant, May 6, 1825, who patented a post-line railway carrying a rail on top and vertical supporting wheels carrying panniers of wood, upon each side. He printed a pamphlet upon it, which was published in Boston, April 30, 1827.

J. Stimpson, June 3, 1830, also patented a single post-line wooden way, having side strips upon the posts.

In the patent of Bryant and Hyett, June 13, 1831, a vertical wheel is shown on a post-line railroad, with the load supported by it hanging down on each side of the posts. A similar patent is J. Richards', patented March 9, 1832.

But the nearest approach to the method adopted in the system under consideration was that by U. Emmons, in the United States,

April 17, 1837, who, in addition to the post line, single rail and wheel on top carrying the car pannier-fashion, and which extended down upon each side of the posts, employed side rails upon the posts upon which run horizontal steadying wheels for the lower part of the car.

July 2, 1872, a patent by E. Crew shows inclined steadying wheels.

To conclude this brief review of these crude and disconnected ideas but two more need be named.

The "Cameron" Pontoon Cart, proposed for South Africa, may be regarded as the simplest possible form for a railway. It consisted in fastening to the ground by rough, notched sticks a line of hollow logs cut lengthwise in halves, not unlike a wooden house-gutter in appearance. In this groove was a single wheel carrying a basket with arms on each side. This "wheel-barrow principle," as it is called, required the equilibrium to be maintained and propelling power furnished by men or animals. Also log railroads have been used, one by Richardson Brothers, at a mill near Truckee, Nev.

This conception, elevated on posts about three feet from the ground, was an idea suggested by J. L. Haddam, Engineer-in-Chief of the Ottoman Government, for a military railroad, and a section was built, with engine and rolling stock, the latter being in form like an inverted V, or on the "camel saddle" principle, hanging upon each side.

The single-rail railroad, so-called, built at the Philadelphia Exhibition in 1876, over Belmont Ravine, was invented by Gen. Le Roy Stone, of New York. It was elevated about thirty-five feet and was about 500 feet long, really consisting of *three* rails instead of one, the section being not unlike the letter A, with a rail at each angle of the triangle. The supporting rail was at the top, the lower rails carrying the horizontal steadying wheels for the saddle-bag car. It was previously built at Phœnixville, Pa. The engine was a rotary one of the La France pattern and connected direct to the supporting wheels by gears instead of cranks. One fatal objection to it seems to be its inability to turn curves.

Thus, while some of the ideas mentioned above undoubtedly enter as elements in the system under consideration, it cannot be said that any of them resemble it closely. It is a fact that this

plan existed previous to the designing of the New York system, and was offered at the time the latter had been determined upon. Generally speaking, the differences from any previous ideas proposed are that it is a truck system like the ordinary railway system, and as such adapted to turning curves with facility. Then, it is *not* a single rail system, but has four rails instead of one, two or three, and the supporting wheels for the load are the lowest instead of the highest rails where more than one is employed. It also has four supporting wheels for each truck, or the same number as the ordinary railroad, which was not the case in the previous plans.

These early ideas were not practical; they had no truck system, and nobody would put in money to develop the practical details. As in the case of the telephone and other great improvements, it is the man who can develop the crude ideas, put them in practical form in all their details, and who creates a new and useful appliance by a new application of principles, though they be very old, who is entitled to the larger share of credit? In considering a railroad, unlike a machine which may be complete in itself, we must have a *system*, which is complete. Previous attempts have failed, because the system necessary could not be carried out without meeting objections fatal to success. Besides, so far as appears, but few of those mentioned ever advanced beyond the conception stage to anything like a practical working.

APPENDIX III.

RAPID TRANSIT AND ELEVATED RAILROADS.

PROOF OF ACTION OF FORCES ON THE MEIGS WHEELS.—In *Fig. 139* let *a G* be the vertical force due to gravity acting downward upon the wheels and guides. We may separate this central force into two vertical and parallel forces *b w*, *b w*, whose point of application is at the central point of junction of the axles and wheels. Now, the force *b w* may be resolved into the two forces of which it is the resultant, *b s* and *s w*, at right angles. *S w*, at right angles to the axle *a s*, tends only to transmit a pressure through the centre line of the wheel, or normal to the rail at *c*.

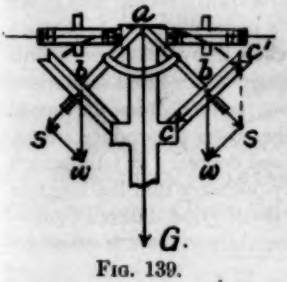


FIG. 139.

If we consider the axles produced until they meet at *a* as a rigid frame, being

so constructed in the truck frame as to be immovable, two motions only are possible. (1.) A rotary motion of the point *a* in an arc passing through *a*, in which case the arms *a s* would slide through the wheels, which motion is prevented with the least supporting force by the position of the two balancing wheels pressing horizontally at the point *a*, or exactly opposite to the tangential force which would cause rotation. (2.) Since the angle cannot rotate, the effect of the load producing the force *b s* tends to crowd the axles through the wheels and to increase or spread the angle *s a s*, the direction of the force being *b c'*. Since this is balanced by a rigid resistance presented by the truck frame itself, its reaction is equal and opposite to the stress caused by the force *a s*, and produces a pressure, *b c*, also normal to the axle and rail at *c*, or directly through the centre of the wheel.

Therefore, the wheel runs as freely in the inclined position as if it were running over a horizontal surface, and would do the same if it had a flat tread parallel to the axle, and without flanges or hub bearings, when it would lack only a guide.

To supply this, either hub bearings must be provided, which are inadmissible, to prevent the wheel from moving out of position, up or down upon the axle, or light flanges to keep it upon the rail. The wheel itself rolls as freely as any wheel rolls over a plane surface. Neither flange in a flat tread-wheel would bear any portion of the load (except the small load due to the weight of the wheel itself, which, of course, acts vertically downward upon the upper flange), but only serves to guide the wheel in position.

Since the direction of all loads on the car is the same as the force of gravity acting on the trucks' weight, the action will be the same for all, light or heavy loads, equally. F. E. G.

OZONE FROM PLANTS.—Dr. J. M. Anders, in connection with Dr. G. B. M. Miller, has been continuing his experiments in plant transpiration, and in the *American Naturalist*, for September, contributes a paper upon the exhalation of ozone by odorous plants. The conclusions reached by his experiments are as follows: (1.) Flowering plants, including odorous and inodorous, generate ozone, the former, however, much more actively than the latter. (2.) So far as tested, scented foliage possesses the power to produce ozone, and in the case of pine or hemlock foliage in marked degree. (3.) Inasmuch as no reactions occurred on rainy days, it is highly probable that the function demands the influence of the sun's rays, or, at least, good diffused light.—*Botan. Gazette, Sept. and Oct., 1885.*

MECHANICAL APPLIANCES IN TOWN SEWERAGE.

By Geo. E. Waring, Jr.

[*A Lecture delivered before the* Franklin Institute, *January 18, 1886.*]

The general subject of town sewerage has been much discussed during these later years, and the importance of the adoption of some efficient measure for the removal beyond the limits of a town, while still in a fresh condition, of all those manifold wastes of human life and industry which are capable of being transported in running water, is well known. All this part of the subject is far better understood now than it was twenty years ago, or even ten years ago. It is hardly necessary to add further argument to the stimulus in this direction, that is so frequently and so sadly furnished by the repeated occurrence of diseases which, formerly ascribed to the act of God, are now well known to be due to the negligence of man.

Perhaps the short time at our disposal this evening may, with advantage, be directed to the consideration of the mechanical appliances of which works of sewerage consist. Until recently we were guided almost entirely by tradition, "rule of thumb," and "common sense."

Let us suppose that at the outset, in a new settlement, a community established itself on both banks of a brook which could be depended on for a supply of water, and for the immediate removal of surface drainage. As the community grew, it resorted to the better source of water to be found at greater or less depth under ground, and the brook become only a drain. When it got to be a nuisance, from its irregular form, and as it became important to make use of the land along its immediate banks, its sides were walled. For the convenience of traffic, roads crossing it were bridged. In time it was found necessary, as a matter of convenience and to get rid of its unsightly appearance, to cover it over. Little by little neighboring houses discharged their wastes into it, generally under restrictions against the introduction o fœcal matter, based upon the erroneous notion, so long prevalent that fœcal matter was the only seriously offensive waste discharged from houses. Often this covered brook, now become a covered common sewer, remained for generations in that condition. Indeed

such drains still exist in our oldest and largest cities, notably, one in Broad Street, New York, in the heart of the Wall Street district, which is still the only outlet of the drainage of a considerable population, but concerning the condition of which we have only traditional knowledge.

Very often water courses existing under the condition above depicted are not merely walled and covered over; their place is taken by large mason-work conduits constituting a greater or less improvement on the ruder device.

This is the origin, and this the type, of town sewerage as generally known in this country and elsewhere. The sewers of Paris had a similar origin and perform a similar office. Some of the larger ones among them, the only ones that the public is allowed to inspect, are applied to the further use of furnishing channels for water pipes, electric wires, etc. They were formerly used for gas pipes as well, but explosions due to leakage of gas made it necessary to abandon this use.

Pretty nearly the whole of London is sewered on a similar system, and, as London and Paris are established authorities and trusted examples of municipal work, the system has extended elsewhere. The considerable use of large pipes as a substitute for brick conduits in London, and subsequently in other English towns, has furnished an example which has been followed here and abroad.

The sewer of antiquity, even of comparatively recent times and in by far the majority of cases to this day, is constructed in a more or less modified form on the theory that it must remove surface wash from streets, the outflow from industrial establishments and the wastes of houses.

Nearly forty years ago the idea was advanced in England that there would be a sanitary and economical advantage in separating street water—an uncertain and constantly-changing quantity—from the more regular flow of industrial and domestic wastes. This was the origin of the separate system of sewerage. Though then, and still, called by this name, the separation in English work has been only partial. It has been decided by the courts there that a house-owner cannot be compelled to make two drains from his premises. He is, therefore, allowed to discharge the rain water falling on his yard and on his roofs into the public sewer. This has the

advantage—more important there than here, because of the much greater frequency with which it rains—of affording a certain irregular flushing to remove deposits from the sewers. It has the disadvantage—much less there than here, because of the infrequency of torrential rains in England—that it requires the sewers to be constructed of an unduly large size as compared with what would be necessary for the immediate purpose of removing foul wastes The English separate system, which is in many respects a great improvement over that formerly prevalent in that country, has been proved by long experience to be reasonably well adapted to the conditions by which its use is regulated.

The argument in favor of this separate system is a strong one. Large storm water sewers, however well they may be flushed during storms, are very liable to the formation of deposits during dry weather, because the mere thread of a stream that they ordinarily carry is not sufficient to prevent the retention of organic matters which, during their retention, undergo putrefaction and give off objectionable gases. The admission of street wastes increases very much the amount of deposit, and, while matters coming from the street are less offensive under putrefaction than are ordinary household wastes, they are often bulky and heavy, and constitute a nucleus for the retention and accumulation of fœcal matter, and other putrescible substances which, without their presence, would have a better chance to be washed away in the flow. Owing to their much larger size, these storm water sewers are more costly than the smaller separate sewers. As the ventilation of sewers, as generally constructed, is extremely imperfect, they often contain a confined atmosphere which, on the sudden increase of the volume of water during storms, is forced past the protecting traps into the street and into houses. Viewed merely as a channel for the discharge of water which would do harm if not properly removed, the storm water sewer, as now made, leaves little to be desired. As a channel for the removal of foul matters, it is, as a rule, completely effective only during heavy storms. Perhaps the worst charge that can be brought against the system is the extreme offensiveness of the contained air of such sewers. Any one who has had experience as I have had in the inspection of works of this character, cannot fail to have observed the almost absolute uniformity with which their atmosphere is contaminated by the products of putrefaction.

Another serious objection to storm water sewers has been developed by the modern requirement which is imperative, in so many cases, to make some other disposition of their flow than its simple delivery into a river or harbor, or into the sea. There are a few favored localities, but they are very few, where such disposal is final and unobjectionable. The necessity is already realized in many places, and is fast being realized in others, either to extend and improve the outlet by pumping, or to purify the effluent more or less completely by mechanical precipitation, or by agricultural irrigation. If sewerage is to be pumped, it is important as a measure of economy to reduce the amount to be so handled as much as possible; to this end, it is desirable that there be excluded from it all water which may without disadvantage be disposed of by natural flow. If the more obviously offensive portions of the sewage are to be removed by mechanical precipitation, it is important that the volume be kept small, and that it be as nearly regular as may be, day by day. If it is to be used as a fertilizer, or is to be purified by distribution over land through which it may be filtered, it is especially important not only that the volume be kept small and regular, but that particularly during rainy weather, when the land is least capable of receiving it, its volume be not inordinately increased by adding to it mere surface flow which might find another and relatively inoffensive outlet.

It is quite usual now, where storm water sewers are used, to make provision for the disposal of the increased flow during storms by means of relief overflows. This would serve a very good purpose if the storm water would be obliging enough to flow on top of the foul sewage, escaping at the overflow in a reasonably pure condition. Unfortunately, the whole mass becomes thoroughly mixed; the foul flow is greatly diluted, and the overflowing excess is greatly contaminated. This is the most serious objection to the relief-overflow system, but there is another which, though generally lost sight of, is by no means unimportant. The overflow weir must be fixed at a certain height; unless it is so high that it will surely retain in the main sewer the maximum flow of an average day, which occupies ordinarily but a very short time in the forenoon, some of this maximum flow will escape daily at the overflow outlet. If, to provide against this, the overflow weir is placed somewhat above any possible elevation of dry weather flow, then

even a very light, continuous rain, will increase the daily discharge at the main outlet to very many times the volume due to house drainage alone.

Where the English separate system is used, supposing the same restrictive requirements to obtain, a similar method of relief overflows must necessarily be adopted, producing the same difficulties, though perhaps in somewhat less degree.

Another serious disadvantage, which has been recognized only within a few years past, and which applies in even greater degree to the smaller English separate system than to the storm water system, is due to the enormous amount of air carried into a sewer by the rapid flow of roof water down the leader pipes. This flow attains great velocity and force. It never occupies anything like the full bore of the leader, except during very heavy storms, and at or near the top. In its descent it carries forward, with force, a great amount of air; this air, entering the sewer, becomes impounded and accumulates under such pressure as to force a final relief, often with great power. Instances have been cited where sewage driven back through a house drain, has spirted up through a kitchen sink with such force as to strike and besmear the ceiling; and where iron man-hole covers, luted somewhat securely into their position with dirt, have, on giving way under the increasing pressure, been blown high into the air. These effects and similar ones, even the perceptible blowing of air through the traps of fixtures in a house, are often due to the air carried in under accumulating pressure through roof leaders, and, to less degree, through street inlet basins.

It is this effect of air-compression, added to the inadequacy of sizes, which may be sufficient in England, to cope with our violent rain bursts, which makes that system so unsuited for this country.

If we assume that the systems above described are for any good reason necessary, and that relief from their disadvantages is to be gained by ingenious mechanical appliances, then we must confess that modern effort has been skilful and effective in giving relief.

Some works with which I have myself had the good fortune to be connected would seem to indicate that relief is to be secured rather by avoidance and prevention than by remedy.

Long impressed with the great disproportion between the sizes

of sewers and the work that they had to do during at least ninety-five per cent. of the time, I had an opportunity to test the actual dry weather requirements, by gaugings made in a number of cities in different parts of the country. The result was conclusive, and was all in one direction. Among other records is that of a large sewer in Milwaukee, furnishing the only means of outlet for a population of 3,177, having a very slight fall, and having the initial velocity of its flow arrested during the trial by a dam built across it. In this dam an ordinary six-inch sewer pipe was inserted. The greatest depth of flow during the forenoon of washing day—the greatest flow of the week—reached in this pipe a depth of only five and one-half inches.

Based on these demonstrations, I laid out a system for the sewerage of Memphis, in which the size of all lateral sewers not more than 2,000 feet in length was restricted to six inches. There are now about forty miles of sewers on this system in Memphis, and of these more than eighty per cent. are only six inches in diameter. Unless accidentally obstructed, not one of these six-inch sewers has ever been known to run half-full; many of them, too, are laid on moderate grades. The success of this work has led to the construction of sewers of the same diameter in Omaha, Pullman, Ill., Kalamazoo, Little Rock, Leavenworth, Birmingham, Ala., Norfolk, Pittsfield, and Chelsea, Mass, Keene, N. H., and on a small scale in other places. A large experimental system on the same plan has been working constantly in one of the worst quarters of Paris for more than two years.

If no other result had been accomplished by this work, it is much to have had it so universally demonstrated under such variety of conditions, that a six-inch sewer is fully adequate to the performance of the duty ordinarily imposed, so far as house drainage is concerned, on very much larger ones,—sewers costing more to construct, more difficult to ventilate, and much more difficult to keep clean.

In other words, considering a tube as the chief mechanical appliance for town sewerage, we have learned, so far as the removal of filth is concerned, that it will be greatly cheapened and improved by having its size reduced nearly to a minimum.

We have learned by this part of the work that the simple function of carrying a stream of sewage produced by a considerable population may be performed by a six-inch tube.

If we consider some of the mechanical adjuncts of the Memphis work, we find that an equal improvement has been effected in the condition of the contained air of the sewer. A large tube, receiving liquid and solid matters, has, at least during the upper part of its course, too shallow a current of liquid to carry all of the solids forward; some of these are inevitably stranded by the way, other solids being gradually added to them, and all of the conditions favoring putrefaction. Putrefaction in a sewer is like putrefaction in a cesspool; it produces offensive and pernicious gases; it probably develops the growth of dangerous micro-organisms, and it produces, as the sum of its results, that dangerous compound of stench and infection called "sewer gas."

In the storm water sewer, as has already been hinted, the accumulation of deposits is favored by the introduction of rubbish from the streets. In the English separate sewers, the accumulation is considerable, because of the considerable radius necessarily given to the channel. In both cases, theoretically at least, each storm introduces a sufficient amount of water to wash these accumulations away; and in the best of such conditions during a storm the sewer is thoroughly cleansed. Unfortunately, no sooner does the rain cease than deposit and accumulation begin again, producing after a few days the former objectionable condition. So uniform has been this result that to most persons the word "sewer" necessarily implies "sewer gas," and it is one of the most difficult tasks of the sanitarian to show that the supposed cause can exist without the assumed effect.

As sewers were universally built before the Memphis work was done, the assumption was correct. There was introduced there, however, another condition which entirely altered the state of affairs. Having, because of the inadequacy of such small sewers to carry rain water, deprived them of even the occasional flushing that rain water would afford, it became necessary to adopt other means of cleansing.

For this purpose there was placed at the upper end of every branch of the whole system a small brick reservoir, built under the street, with a capacity of about two hogsheads, fed by a trickling stream from the water supply, and provided with an automatic siphon by which, when the tank was filled and began to overflow, the whole volume was rapidly discharged into the head of the sewer,

assuring it a thoroughly cleansing current throughout all of its upper portion, where the natural stream is never strong enough at any time during the day to remove all that is delivered into it.

The source of foul air was thus very largely, but not with absolute completeness, removed; there remained still to be guarded against the smearing of the walls of the sewer which, without ventilation, would of itself be sufficient to produce a very foul condition of the small amount of air that such sewers hold. The only means for obviating this difficulty seemed to be to secure a most copious ventilation, much more copious than would be possible with the large sewers of the combined system.

The persistence of certain habits of thought has been curiously illustrated by those who have discussed the ventilation of the Memphis sewers on the basis of systems of ventilation applicable to large sewers. Even so distinguished a man as Professor Baumeister has declared that, as air moves more freely through large channels than through small ones, therefore the ventilation of the Memphis sewers must necessarily be less effective than would be that of larger sewers with the same means of inlet and outlet, and with the same frictional forces acting upon it. He, and numerous others who have agreed with him, have disregarded the important consideration that, in order to make this reasoning correct, they should have given to the large sewer the same *proportional* means of inlet and outlet, and the same *proportional* effect of friction. For example: Take a six-inch sewer carrying a stream two inches deep, with a given velocity, having a length of 200 feet, and having eight occupied houses on each side of the way. Suppose these houses to be provided, as in Memphis, with untrapped four-inch house drains and soil-pipes opening into the sewer above the water-line and delivering above the roof with an open mouth. Under such conditions we have in this 200 feet of sewer about thirty-three cubic feet of air subject to the inward and outward currents due to sixteen four-inch pipes, having a combined sectional area of about 200 square inches. The area of surface of a stream flowing two inches deep in a six-inch sewer 200 feet long is about ninety square feet. As the stream flows, it produces a frictional effect on the volume of air above it, which, in order to renew the whole atmosphere of the sewer, has to impart its movement to only thirty-three cubic feet of air.

Let us now suppose the sewer to be three feet in diameter and to carry the same volume of water. The flow, having much less hydraulic mean depth, will have less velocity, probably enough to counterbalance its increased area in contact with the air, so that it will be fair to ascribe to it the same influence in moving the contained volume, but that volume is now increased from thirty-three cubic feet to 1,414 cubic feet. As a much greater area of the wall of the sewer will be covered and laid dry with fluctuations in the flow, the amount of smearing will be greater and the amount of contamination will be in proportion. This will, in part if not entirely, make up for the greater dilution which the larger volume affords; so that if we consider only the effect of the stream we see that the purification of the contained air can by no means be so great.

In the case of the six-inch sewer, the proportion between the square feet of ventilating area furnished by the sixteen house-drains and the cubic feet of contained air, was as one to twenty-five (about); in the case of the three-foot sewer it is as one to over 1,000. Assuming, as we safely may, that the force applied in the case of the six-inch sewer is very much greater than is needed for the purification of the six-inch pipe, we see that purification is practically complete; and observation in the case of all six-inch sewers constructed on the Memphis system, of which I have had knowledge, shows, not a comparative but a complete absence of the peculiar odor of organic putrefaction. That is to say, in such sewers "sewer gas" does not exist, and the fear engendered by the present almost universal condition of town sewers becomes entirely unfounded.

In addition to the effect of ventilation through house drains and of the friction of the stream ordinary flowing, a sudden greatly increased effect is produced by the discharge of the flush tanks. These send through the sewer such a volume of water, flowing at such high velocity, that practically all of the air in advance of the wave is driven forward with force and sent out through the house drains as they are successively reached, the partial vacuum following the wave being supplied by a sudden indraft through those which have been passed.

Incidentally to the discussion of the Memphis system, it is appropriate to speak of another of the mechanical appliances of

sewerage known as the manhole. The manhole is a well, built from the sewer to the surface of the street and there properly covered, through which access is obtained to the channel for observation and for cleansing. Guided, as we are all guided, by fixed traditions, I planned to construct manholes at regular short intervals over the whole work. When the estimates came to be made, it was found that the total cost of construction would be more than the community was able to pay; something had to be cut down. It seemed that the safest thing to dispense with would be the manhole on the small lateral sewers. This effected a very great saving and, with the help of a restriction of the size of the main sewer to what was necessary for present purposes, the total cost was brought within the prescribed limits.

Curiously, the chief criticism that has been made on the system here adopted related to the absence of manholes—which was not a part of the system at all. The subsequent modification of the work to which the abandoning of manholes led, was the introduction of handholes at short intervals. It was found that when obstructions occurred, and they were very easily located by their effect on house drains, it was necessary to break through the top of the pipe to remove them. The openings thus made could not be satisfactorily closed. There was then introduced, in the further work, a pipe having an opening at its top and a moulded cap of the same material to fit it. The location of these caps being known, it was always easy to get access to the sewer within not more than fifty feet of an obstruction. Later, some of these openings were covered with caps having branches into which six-inch pipes were inserted, the standpipe being carried up to within about two feet of the surface of the ground. This greatly facilitated the work of inspection, the street being little disturbed by excavating to this slighter depth. These appliances have been effective and have now become a regularly adopted feature of the system wherever applied.

Owing to obstructions due to special causes, there have been built in Memphis six manholes on six-inch sewers; on one lateral within a length of 700 feet, there are four manholes, and on another there are two manholes 300 feet apart; these are the only ones on about 180,000 feet of six-inch sewer, being an "average" of one to about five or six miles. So far as I have been able to learn, there

is no disposition to build more. At the same time, but for the cost of the work it would unquestionably be an improvement to build frequent manholes leading *to* but not *into* the pipe. Such small sewers are so easily obstructed that an opportunity should not be given to throw into them things which it may be desired to conceal. The sewer pipe should be exposed at the bottom of the manhole, but entrance to it should be through a handhole with a well secured cover.

As a substitute for manholes, handholes and standpipes, a recent improvement is worth consideration. It is the invention of Burton R. Phillipson, of Dublin. He introduces at intervals a branch with a funnel-shaped junction with the sewer, so as to afford no occasion for floating objects to lodge, and he continues this with an inclined pipe nearly to the surface of the ground, covering it there with a special casting, taking the place of the ordinary manhole cover and easily opened for inspection of the sewer. As this pipe inclines toward the axis of the sewer and has a rounded connection with it, a stout telegraph wire, which is after all the best device for inspection or for cleansing, can be inserted, in the absence of angles, for a distance of several hundred feet. Incidentally to this arrangement, Mr. Phillipson has invented a very ingenious device for cleansing the sewer or damming back water for special flushing effect in case of need. He uses a soft india-rubber ball, or elongated bag, capable of being expanded to rather more than the full size of the sewer; to this an air pipe is connected; it is inserted into the sewer a little below the branch, and is then blown up until it makes a tight fit; the pressure of water accumulating behind it only makes it fit the tighter and in this way sewage may be dammed back to the surface of the street. Any partial obstruction higher up the stream may then be driven from its attachment by the forcible working of a plunger in the vertical column of water, imparting the shock to the contents of the sewer above. When the proper flushing volume has accumulated, the opening of the air valve will speedily release the rubber plug which may be drawn out, allowing the whole volume to flow forward.

Still following the traditions, the public, many of our boards of health, and not a few of our engineers, still insist that whatever else is done and whatever other safeguards are provided, the drainage works of the house must be absolutely shut off from any

form of connection with the atmosphere of the sewer by a trap on the main drain.

It would be out of place here to enter into a full discussion of the subject, but it seems pertinent to observe that this is another case where prevention is better than remedy; and that, disregarding all other bearings of the case, if the universal ventilation of the sewer through house drains will secure the abolition, or the very great mitigation, of the sewer gas difficulty, it is better to accomplish this in this way than to allow the dreaded demon to exist, as he surely will in the absence of such ventilation, and then try to keep him out of the house by the interposition of a few quarts of water.

It is also to be said that all communication between the house itself and the pipe through which its wastes are discharged must be shut off by traps at all fixtures, which shall be absolutely reliable under all circumstances. This being done, even very foul air coming from the sewer will pass out through the open soil-pipe, rather than pursue a tortuous and obstructed course through small branches into our rooms.

A cardinal element of the system used at Memphis is the automatic flush-tank, already referred to, placed at the head of each branch sewer of the whole system. It is quite important that whatever device may be used for flushing the sewers should be arranged to work automatically and with certainty. It not only costs inordinately, in money and in water, to flush sewers by hand through their manholes, but the performance of an essential duty like this, the neglect of which, even for forty-eight hours, would establish a foul condition in the sewers, depending on personal attention, and on the direction and control of the average underpaid and overworked city official, cannot be relied on.

Automatic flush-tanks are of various sorts and kinds. Perhaps the oldest and most familiar is the tumbler-tank, which becomes overloaded on its discharging side when nearly full, and then tips and spills, dropping back to its former position after it has been emptied. This tank is costly, for its joints and bearings must be rust-proof; its balance and counterpoise must be nicely adjusted, and, however carefully it may be made, it is pretty sure, sooner or later, to get stuck up or down, or more often at the half-way point, and to refuse to act.

There have been many recent inventions of flush-tanks, some of them very ingenious, and some of them very good and practical. The only one that has come to my notice which seems to be absolutely unobjectionable is what is known as Rogers Field's tank. Mr. Field is a skilful and careful engineer, who has long made a specialty in England of works of sanitary drainage. The siphon by which this tank is discharged has been with him a plant of slow growth, and its ultimate perfection was the result of a long series of experiments. It has the very great advantage—one might almost say, considering the importance of having everything connected with a system of sewerage so adjusted that it will take care of itself, the indispensable advantage—that it is entirely without moving parts. It is practically as simple as a mill dam. Some minor modifications of form have been made in this country, as the result of experience and of observation, but the original principle remains precisely as Mr. Field devised it. Its peculiarity is confined entirely to the discharging limb, and it makes practically no difference whether its form be a bend, or what is known as an annular siphon. Let us consider the annular form:

A reservoir of a certain size is provided with a standpipe, passing through its bottom and having its top at the level to which it is desired to fill the tank. This standpipe, for a tank of ordinary size, is four inches in diameter. Its lower end under the tank is not connected directly with the head of the sewer, but delivers into a basin, which, when filled to its overflow point, holds water just in contact with the lower end of the standpipe, sealing it, but not sealing it to any considerable depth. The upper end of the standpipe is provided with an adjutage, or funnel, from which the falling water drops clear of the sides of the pipe, and falls directly into the water in the lower chamber. As it falls it carries bubbles of air with it. Some of these bubbles rise again into the standpipe, but some are driven beyond its edge and rise into the chamber outside of the pipe. So long as this remains an uncovered standpipe, this process might go on forever without withdrawing more water from the tank than would naturally overflow at its top.

Let us now take a dome, or a larger pipe, say eight inches in diameter, tightly closed at the top, and pass it down over the standpipe so as to leave a space between the two for the whole

circumference. This space now becomes the receiving limb of a siphon, and, if siphonic action is once established, it will continue to run until the level of the water in the tank is carried down to the bottom of the outside pipe and air is taken in. There is nothing novel in the annular form of siphon.

What takes place in Field's siphon is this: The top of the standpipe being sealed by the water contained between it and the outer pipe and the lower end being sealed by contact with water in the discharging chamber, we have, at the moment when the overflow begins, a certain volume of confined air at natural atmospheric pressure. A small stream overflowing and dropping from the adjutage to the water below, carrying air bubbles down as described, and some of these bubbles escaping outside of the foot of the standpipe, there is a gradual removal of the air; the pressure is reduced, water rises a little into the lower end of the pipe and the rapidity of overflow is proportionately increased. The increased flow carries out more air, and after a few moments' operation—longer or shorter according to the volume of the stream added to the reservoir—so much is removed, and the falling stream is so much increased that the remaining air is soon discharged, and the siphon works with a solid stream.

In Memphis, the tanks have a discharging capacity of 120 gallons—about two hogsheads. If accurately adjusted, a stream barely large enough to fill the tank once in twenty-four hours is enough, after it is filled and begins to overflow, to bring the siphon into action within from five to ten minutes, and the entire volume is discharged, in some cases in as little as thirty-five seconds.

It was found that while the siphon could be brought into action as described, something further was needed to make its breaking complete; that is, to get rid of all of the water contained in the siphon itself after the first checking of the flow by the first intake of air. This could best be done from below. It is accomplished by the operation of what is called a subsidiary siphon. This, in its simplest form, is a pipe carried from the discharging chamber over its elevated overflow point and down into the outlet. While the main volume is being discharged, a part of it passes through this pipe, which continues to act as a siphon after the flow through the main siphon has ceased. Its further supply of water comes from the outlet chamber at the foot of the standpipe, the level of whose water

is thus reduced below the lower end of the standpipe which, becoming unsealed, loses its entire charge, the contents of the receiving limb dropping back into the tank, and the contents of the discharging limb falling into the chamber and passing off through the subsidiary siphon.

The water of the subsidiary siphon having been lowered an inch or more below the mouth of the standpipe, a new discharge of the tank cannot be set up until it has been refilled and the overflow has continued sufficiently long to fill the outlet chamber again and thus reseal the lower end of the discharging limb.

It has been found in practice that a small pipe adequate to the emptying of the discharging chamber is subject to stoppage from the accumulation of rubbish of one sort or another before its inlet.

This difficulty was obviated by using a diaphragm in the main discharge which, while not materially reducing the capacity of the outlet, gave a subsidiary siphon of sufficiently large area to carry off foreign matters without choking.

Then another difficulty arose. The outlet of the subsidiary siphon being so large, air was taken back through it and its action was stopped before the desired effect was accomplished. To cover this difficulty a block or dam is placed in the outlet in front of the subsidiary siphon, holding back the flow to such an extent as to prevent the admission of air until the work of emptying the outlet chamber is done.

Still another difficulty was found in practice: As the standpipe or discharging limb was originally made, it was but little larger than the mouth of the adjutage or funnel. Blisters of rust accumulating on the inside of the pipe sometimes projected so far out as to catch the falling stream and lead it down into the outlet chamber along the side of the pipe without carrying out the air. To remedy this, the pipe was made considerably larger, increasing the space between the edge of the funnel and its outer wall, and then drawn in at the bottom so that the water should fall very near to its side and allow a larger proportion of the air bubbles to escape outside.

These modifications and some improvements in construction not necessary to describe here having been made, the siphon is now absolutely and permanently effective. It is simple in construction and may be depended on to perform its offices year after year with absolute certainty. It may be, of course, that the ingenuity that

is constantly applied to the subject will result in producing some other form of automatic device that will be even cheaper and better than this; but thus far nothing has been produced at all comparable with it.

There is a good field for invention, and much need for it, in the matter of outlet, especially for the drainage of low-lying districts and of town areas which, while they may have sufficient fall to low water mark, have their outflow obstructed twice a day by the rise of the tide.

One of the most ingenious things that has been devised in this connection is what is known as Shone's ejector, somewhat used in England, and now contemplated for application at Sacramento. This is a sort of self-acting compressed air pump, controlled by automatic valves operated by floats. A tight reservoir of any convenient size is built in the ground at the lowest point of the district it is to serve, and to this the sewage of the whole district is led. Its outlet communicates with a force main; its air vent is open and its outlet is closed. The sewage flows into it, and when it is filled, operates floats, which close the air vent and admit the pressure by which the contents are driven through the force main. This system of pumping is especially applicable to towns having numerous depressed points in no easy communication with each other, or for very large, wide areas where sufficient fall cannot be obtained without a depth of cutting that would be very costly in unstable soils. Its chief drawback relates to the loss of power in compressing air, which is serious; and to its moving valves.

Generally it would be cheaper, maintenance considered, to lay one large, low main sewer, by tunnel if necessary, to carry the out-fall level back with little loss for fall, or to do the pumping all at one central station, applying the power directly to the pump rather than to use it for the compression of air.

Perhaps, too, the same end may be accomplished by the direct application of power at as many different points as may be necessary, by means of gas engines. These are about being used for the pumping of the whole sewage flow of the borough of Stamford, Conn., and that experiment will give us the information necessary to determine whether or not this power may be economically applied at different points throughout a town.

A case has recently occurred in the carrying out of a plan of my own, in which it was necessary to surmount an unexpected obstacle.

In Norfolk, Va., the entire sewage of the city is discharged into a pumping well, in which the mouth of the suction pipe stands at a point ten and one-half feet below low water mark. The main sewer of a system covering about one-third of the town was to be discharged into this well, and in order to reach branches necessarily laid at about the level of high water in the most distant part of the town, a low grade for the main sewer had to be preserved. It was contemplated to lay for this a pipe sewer eighteen inches in diameter about fifteen feet below the surface for a considerable part of its length. It was soon found that the soil in which it would be necessary to work was an almost impassible quicksand, and there was reason to fear that in passing a very large Masonic temple its foundations would be disturbed by the running of the earth. The scheme had to be abandoned. The sewers for the upper part of the system had already been laid, with the aid of active pumping. In devising the means for relief, I had recourse to a plan I had recommended for the drainage of a town in Holland, but not there put in practice. A well was sunk at the end of the completed main, about 1,700 feet distant from the pumping well, and was carried down several feet below the level of the intake of the pumps, its total depth being about twenty-one feet. Into this, the main sewer delivered. From it, at a point six inches below the sewer inlet, there started a fourteen-inch iron pipe, which was carried up the well and thence along the street, but little below the surface, turning down into the pumping well and being finished with a return bend, which would always remain full of water and would serve as a permanent sealing trap. The overflow of this sealing trap is a few inches higher than the intake at the open well. This constitutes a siphon by which the sewage flowing into the upper well is carried upward about thirteen feet and then forward into the pump well. As sewage rises in the upper well, it flows out at the mouth of the siphon, the head required for its discharge being practically what is due to the theoretical flow through a fourteen-inch pipe 1,700 feet long of the discharge of an eighteen-inch pipe, which will rarely, if ever, run half full. This siphon has now been working for some seven months, and it is

said by the city engineer to be an entire success. It was charged by a pump attached to the main steam pumps and connected with the apex by a two-inch iron pipe. This pump is operated for a few minutes every day to remove accumulated air.

Had I not recently had occasion to read a paper in this city on the disposal of sewage, including the destruction or utilization of its wastes, I should have regarded that subject as constituting a better compliance with the invitation of your Professor of Chemistry. The proper applications of the mechanical appliances used for the removal of the waste of population, need, however, to be well understood even by students who give their attention chiefly to the chemical problem connected with disposal and utilization.

CONSTRUCTION OF A LARGE PRONY BRAKE.

By Prof. R. H. Thurston.

In planning the investigation made by Messrs. Gately and Kletzsch, of which an account appeared in the Journal of the Franklin Institute, of October last,* it was first necessary to secure some means of controlling the velocity of the engine with certainty and safety, at the highest speeds and greatest power that it could be expected would be attained. The usual method was obviously the best for the purpose, and the design of a Prony brake thus formed a part of the problem to be attacked by the investigators.

The form of brake finally concluded upon was substantially the same as that used previously by several well-known engineers. It consists of a brake wheel, or pulley, which is keyed on the engine-shaft, and is sufficiently strong to sustain safely the maximum load anticipated. The rim of this pulley is turned flat and very smooth, and is fitted with a flexible brake-strap of wrought iron, or other suitable material, which may be adjusted to such a tension as will enable it to control the engine at maximum power.

The rim is trough-shaped in section, flanges extending inward toward the shaft to a sufficient depth to permit the retention in the circular trough so formed of a stream of water which is used to keep the pulley cool, and to carry away the heat produced by transformation of mechanical energy.

* Journal Franklin Institute, October, November, December, 1885; *London Engineer*, November, December, 1885.

The two ends of the brake-strap are united by a right and left hand screw, in such manner that they may be drawn together and the strap set up to any desired degree of tension. The brake-arms consist of two beams, of wood, forming an < frame, and secured to the strap at the upper and lower sides, and at their junction supported by a strut resting on a platform scale of nice construction and great accuracy. As the engine-shaft revolves, the tendency of the brake-arms to turn is resisted by the scale, and the effort so measured, multiplied by the relative velocity of the engine-shaft and the supported point on the arm, gives a measure of the power expended.

Water is supplied to the pulley-rim, by means of a hose, from any convenient source, and the excess is taken away in a similar manner. The centrifugal action of the rotating mass keeps the fluid in place in the pulley-rim, and the eduction pipe receives the water carried away by it as the tender of a locomotive scoops water from between the tracks, when at high speed. This system of cooling permits efficient lubrication, without admixture of the grease with the water, and secures a perfection of smoothness and uniformity of rubbing surfaces unattainable with the older forms of brake.

The following is an account, in detail, of the designing and proportioning of the brake, as reported to the writer by the gentlemen who so well performed the work. The brake, when constructed, was found to have a very satisfactory form, and worked well under higher loads than the writer had ever before known to be controlled by this means. So far as he was aware, no successful attempt had ever been made to control so powerful an engine with the Prony brake. The smooth action of the turbine better adapts that motor to this system of management, and Mr. S. Webber has used the brake, in that field, at higher powers; but the irregular action of the steam pressure in the modern steam engine introduces difficulties of serious magnitude, when it is attempted to thus handle its constantly varying efforts.

DESCRIPTION.

The brake described below was designed to control a Harris-Corliss engine at Sandy Hook, Conn. It is a modification of the well-known Prony brake, described in Rankine's "Machinery and Mill Work," page 383, § 341. It was designed for the maximum

power of the engine, *i. e.*, taking steam at full stroke, the engine running at 100 pounds pressure, and at 100 revolutions per minute. The diameter of the cylinder being 18 inches and the stroke 42 inches, we have for the maximum power developed:

$$HP = \frac{254{\cdot}47 \times 100 \times 42 \times 2 \times 100}{33000} = 540{\cdot} +$$

The brake was accordingly designed to control the engine when exerting this power, and to be used upon a 5-foot pulley of 24-inch face. The size of the pulley was chosen of this diameter, rather than larger, simply because it compelled less removal of floor and railings about the engine, and would also lessen the cost of construction of the pulley.

Having assumed the diameter of the pulley upon which the brake-strap was to be used, the calculations for the remaining parts of the controlling apparatus is as follows:

Assumed diameter, 5 feet; assumed maximum speed of engine, 100 revolutions; circumference, 15·708 feet. This would give for the greatest linear velocity of the pulley per minute, 1570·8 feet. Dividing the greatest number of foot pounds developed by the engine, at its maximum speed and pressure, by the linear velocity, gives the resistance at the rim of the pulley; or,

$$\frac{540 \times 33000}{1570{\cdot}8} = 11{,}345 \text{ pounds;}$$

which figure is the total friction, in pounds, on the face of the pulley.

BRAKE–BLOCKS.

The blocks used in constructing the brake were 2½ inches thick, 5 inches wide, and 24 inches long, of unseasoned white oak. In order to keep the brake upon the face of the pulley, wooden lugs were attached to the ends of the blocks, which were placed 7 inches from centre to centre, thus leaving a space of 2 inches between adjacent blocks, for diffusion of the heat and lubrication of the pulley. The blocks were attached to the flexible brake-straps by means of wrought iron lag-screws of ¼ inch section, and 2¼ inches in length. The three blocks at the top of the pulley were fastened to the arms of the brake, and were of seasoned birch, as no white oak of the size of these blocks was to be had in the neighborhood.

SIZE OF FLEXIBLE BANDS.

The straps, two in number, were calculated according to Rankine ("Machinery and Mill Work," § 354, page 403).

Let T_1 and T_2 represent the tensions at the ends of the band which embraces the pulley, and let T_1 be the maximum tension.

Then T_1 exceeds the tension, T_2 by an amount equal to the friction between the blocks and the pulley; *i. e.*,

$$R = T_1 - T_2 = 11{,}345.$$

Let c denote the ratio which the arc of contact bears to the circumference of the pulley, f the coefficient of friction between the blocks and the pulley; then the ratio $T_1 : T_2$ is the number whose common logarithm is $2{\cdot}7288\ cf$; or,

$$\frac{T_1}{T_2} = 10^{2{\cdot}7288\, fc} = N.$$

c, the arc of contact of the bands $= 1$, and f, the coefficient of friction between wood and cast iron (well lubricated) was taken at $0{\cdot}2$; then

$$N = 10^{2{\cdot}7288\, fc} = 10^{2{\cdot}7288 \times {\cdot}2 \times 1};$$

or,

$$\frac{T_1}{T_2} = 10^{0{\cdot}54576} = 3{\cdot}5.$$

Having found $R = 11{,}345$ pounds, we have for the greatest tension on the band,

$$T_1 = R\,\frac{N}{N-1};$$

and substituting the values of R and N in this equation, we have

$$T_1 = 11{,}345\,\frac{3{\cdot}5}{3{\cdot}5-1} = 15{,}883 \text{ pounds.}$$

Hence, for the combined tension on the band, and, using two straps, we have for the tension on one,

$$\frac{15{,}883}{2} = 7941{\cdot}5 \text{ pounds.}$$

Taking the tensile strength of such wrought iron, as given by authorities, at 40,000 pounds per square inch, and allowing for a six-fold factor of safety, we obtain for the section of the band,

$$\frac{\text{pull} \times \text{factor of safety}}{\text{tensile strength}} = \text{section in square inch};$$

or,

$$\frac{7941{\cdot}5 \times 6}{40{,}000} = 1{\cdot}19 \text{ square inches.}$$

The nearest band-iron of this section was ⅜ x 3 inches, and, after careful testing, it was found to be of sufficient strength; thus giving, at the same time, the required flexibility, which is of vital importance in the operation of brakes. At each end of the bands, it was found necessary to weld on round bar-iron, to admit of threads being cut for the purpose of tightening and loosening the brake.

As this bar-iron is subjected to the same stress as the bands, the section should be the same; hence, we have for the section of belt:

$$\pi r^2 = 1{\cdot}19;$$
$$r = {\cdot}625;$$

and the diameter should be 1·25 inches. These bars were of unequal length, being purposely so made in order to permit the passing of the angle-iron of the one used in tightening and taking up the wear of the brake. The bands passed through the arms of the brakes and thence through the angle-iron, which was made specially for this purpose, and placed above the arms. This angle-iron was not rigidly attached to the brake; it was held firmly in place by the tightening of the bands and also by means of dove-tailed wedges which were driven home, occasionally, in order to prevent any moving should they have been loosened in any way by the continual tremor of the brake.

ARMS.

The arms were two in number, of 6 x 6 inches of well-seasoned spruce. The length was made 10 feet 6 1 inches from centre of the bearing surface on the pulley to centre of bearing surface on the scale.

This length was purposely so chosen, as it, in the first place, brought the scale beyond the rim of the fly wheel, and, secondly, it greatly facilitates calculations of the horse-power developed—the circumference of a circle, whose radius is 10 feet 6·1 inches, being 66 feet. Thus instead of multiplying by 66 feet, and then

dividing by 33,000 to obtain the horse-power, it is only necessary to divide the product of the net scale pressure and the revolutions per minute by 550, the quotient being the horse-power developed, *i. e.*:

$$HP = \frac{W \times Rev. \times 66}{33{,}000} = \frac{W \times Rev.}{550}$$

The arms were but slightly tapered, so as to get as much weight as possible at the ends, without encumbering the apparatus, and in order to produce a greater stability, and consequently a more uniform running of the engine.

The ends of the arms were connected by a piece of chestnut 2 x 8 x 18 inches, firmly bolted to them, the bolts being turned conical at the ends, and of the same length, so as to insure a uniform bearing on the scale. This was also further adjustable by the wrought-iron ties connected with the bands on the under side of the brake; and, by means of a swivel placed in each tie, these could be tightened or loosened accordingly as one or the other of the bolts were found not to be bearing firmly.

The stand through which the pressure was transmitted to the scale was composed of two uprights, 6 x 6 inches, of white pine, surmounting a pedestal covering the greater part of the scale platform. Upon these uprights was placed a steel plate of ¾-inch thickness, which received the pressure of the bolts. The scale was a "Fairbank's Standard," was carefully balanced, and was capable of accurately weighing 3,000 pounds. All weights used were carefully weighed on a standard balance, and none were used that were found not to be absolutely correct.

THE PULLEY.

It was found necessary to design and construct a special pulley upon which the brake could be used when the maximum power of the engine was being developed. The design and calculation was an important matter, as upon the strength of this pulley depended the safety of the engine and of those assisting in the experiments. Besides, several factors entered in its construction which we have noticed before; as, for instance, the heating and expanding of the rim and arms caused by the friction of the brake; the great normal pressure caused by the tightening of the brake, and the unequal pressure the rim would be subjected to in tightening first one band and then the other.

As already mentioned, it was deemed advisable to make the pulley 5 feet in diameter. In order to clear both the fly wheel and eccentric, it was found necessary to make the pulley of 24-inch face.

As the common segmental arm would give but a very narrow bearing for the rim, the writer advised an arm of T-section, which was found to answer the purpose.

The calculations for the parts of the pulley were made according to Unwin, ("Machine Design"), who gives for the thickness of rim:

$$t = 0{\cdot}7\,\delta + 0{\cdot}005\,D$$

where D = diameter in inches = 60 inches;
and δ = thickness of belt taken at 0·5 inches.
Hence, by substitution,

$$t = 0{\cdot}7 \times {\cdot}5 + 0{\cdot}005 \times 60;$$
$$= 0{\cdot}65 \text{ inch.}$$

The number of arms was assumed at 6; and from the same author, for the thickness at the nave,

$$h = 0{\cdot}1781 \sqrt[3]{\frac{P\,D}{n}}$$

P being the driving effort, 11,345 pounds;
D = diameter = 60 inches; and
n = number of arms = 6;

$$h = 0{\cdot}1781 \sqrt[3]{\frac{11{,}345 \times 60}{6}};$$
$$h = 8{\cdot}54 \text{ inches.}$$

$$h_2 = \text{breadth of arms} = \frac{h}{2} = 4{\cdot}27 \text{ inches.}$$

For h at the rim, we take ⅔ that of the nave.
For h_2 at the rim we take ⅔ that of the nave.
For the thickness of the nave,

$$\delta = 0{\cdot}18 \sqrt[3]{B\,D} + ¼;$$

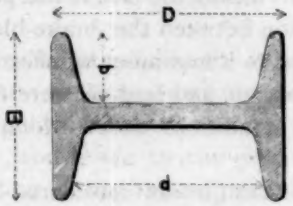
where B is the face = 24 inches;
D is the diameter = 60 inches.

Substituting, we have

$$\therefore \quad \delta = 0{\cdot}18 \sqrt[3]{24 \times 60} + ¼$$
$$\delta = 2\,1 \text{ inches.}$$

The diameter of the main shaft being 9·12 inches, the calculated thickness of the nave was judged rather small, and 2·5 was used instead. The rim was also made ⅛ inch heavier at the centre than the calculated dimension used for the edges of the rim.

CALCULATIONS FOR DOUBLE T ARM.



From Trautwine, page 196, we find for the moment of inertia of this section,

$$I = \tfrac{1}{12} B D^3 - \tfrac{1}{12} (2 b d^3)$$

and, considering the arm as fixed at one end and loaded at the other (Wood's "Resistance of Materials," Eq. (182) page 188),

$$Pl = \frac{R I}{d}$$

where P = load;
l = length of arm;
I = moment of inertia;
R = modulus of rupture;
$d = \tfrac{1}{2} D$.

Load on 1 arm = ⅙ of 15,600 = 2600 = P.
$l = 30 - 7\tfrac{1}{2} = 22{\cdot}5$ inches.
$I = \tfrac{1}{12}(4 \times 8^3) - \tfrac{1}{12}(2 \times 1\tfrac{1}{4} \times 5^3) = 40{\cdot}6$.

Allowing a factor of safety of 3, we have by substituting in the above formula, and transposing,

$$3 \times 2600 \times 22\tfrac{1}{2} = \frac{R \times 40{\cdot}6}{4};$$

$$175500 = R \times 10{\cdot}15;$$

$$R = 17{,}290;$$

hence, the above sections and dimensions are ample.

MANIPULATING THE BRAKE.

The controlling of the engine by means of the brake needed the attention of one man, and was not an easy task. For the purpose of handling the brake with ease, a platform was placed at a

convenient height, and, by means of a long wrench, the tightening and loosening of the bands was easily accomplished. On account of the heating and consequent expansion of the face of the pulley when dry, the friction was increased and caused an unnecessary fluctuation in the speed. To prevent this heating, water was led to the inner face of the pulley from the mill-dam through a 2½ inch fire-hose. By this means, the face of the pulley was kept quite cool, and, as the friction between the brake-blocks and the face of the pulley was reduced to a minimum by effective lubrication (beef tallow, fine flake plumbago, and lard oil were found to work best), the constancy of the conditions under which the test was made was well maintained.

On the whole, this design was considered by the writer one of the best, and its operation one of the most successful illustrations of the application of Prony's invention that he had ever met with; and it has been thought that this detailed account of its design and construction may prove interesting to many others in the profession.

DIRECTOR'S ROOMS, SIBLEY COLLEGE,
CORNELL UNIVERSITY, *Ithaca, N. Y., January, 1886.*

SUMMARY OF ENGINEERING AND INDUSTRIAL PROGRESS FOR THE YEAR 1885.

[*From the Report of the Secretary made at the Stated Meeting, held Wednesday, February 17, 1886.*]

THE PREDICTION, respecting the outlook for the year 1885, which I ventured in the introductory paragraph of last year's summary has been literally fulfilled. This prediction was conveyed in the words "there are signs, however, to indicate that the year we are just entering upon will witness a marked improvement in the industrial situation."

The past year witnessed the removal of several of the most formidable obstacles in the path of prosperity, and a very general revival of industrial and commercial activity: and it closed with these favorable conditions still dominating the situation, and with the general prevalence of a feeling of confidence that the country had left behind it the stagnation and depression of the past few years, and had fairly entered upon a new era of prosperity. The

belief in the settlement of the acrimonious warfare between the great trunk lines of railway which had brought them, and numbers of less important lines, to the verge of bankruptcy, and the restoration of rates for freight and passenger service to a paying basis, were undoubtedly the principal factors in bringing about the improvement in general business which characterized the later months of the past year.

A REVIEW of the iron trade, exhibits the fact that the depression of the previous two years continued until about the middle of 1885, when symptoms of a revival became manifest. The improvement from that time forth, and down to the present, has been uninterrupted, and the feeling among the manufacturers is one of confidence. The steel makers have thus far reaped the lion's share of benefit from this revival of activity, but the other branches of the trade have at length begun also to experience its vivifying influence.

The production of all kinds of pig iron in the United States in 1885, is given by Mr. Swank, of the American Iron and Steel Association, as 4,529,869 net tons, or 4,044,526 gross tons. In 1884, the production was 4,589,613 net tons, or 4,097,868 gross tons. The decrease in 1885 as compared with 1884 was only 59,744 net tons, or 53,342 gross tons.

The reports show that nearly every State and district shared in the increased activity of the second half of the year, and the *Bulletin* says: "As compared with recent years, commencing with the boom year, 1880, the production of pig iron in 1885 presents an exceedingly favorable showing when the depression in all branches of business in the greater part of 1885 is considered."

The production, classified according to the character of the fuel used, as compared with the two preceding years, was given as follows:

	1883.	*1884.*	*1885.*
Bituminous, ...	2,689,650	2,544,742	2,675,635
Anthracite, ...	1,885,596	1,586,453	1,454,390
Charcoal, ...	571,726	458,418	399,844
Total fuel used, . .	5,146,972	4,589,613	4,529,869

The stocks of unsold pig iron in the hands of the manufacturers or their agents at the close of 1885, and which were not required for

the consumption of those who produced it, amounted to 416,512 net tons, or 371,886 gross tons, not more than half of which was charcoal pig iron. At the close of 1884, the stocks amounted to 593,000 net tons.

The total number of furnaces in blast at the end of 1885 was 276; out of blast, 315, a total of 591. In 1884, 236 in blast, 433 out, a total of 669. The number of new furnaces in course of erection in 1885 was twenty-four.

These figures exhibit the fact that a large percentage of our blast furnaces is still idle, and that the productive capacity of the country is largely in excess of the present demands. The same statement will hold good also of steel. The full capacity of our Bessemer works is approximately 2,000,000 tons per year, while the present production—prudently regulated by agreement among the manufacturers—is at the rate of 1,000,000 tons. The immediate danger that threatens to check the incipient prosperity that has come to our iron industry, is that some sudden and unexpected increase in the demand in excess of the ability of the active works to supply, may tempt the manufacturers to run up prices to considerably higher figures, and thus cause the starting into operation of a large number of idle furnaces and mills, the output of which would speedily glut the market and cause a disastrous fall in prices. The harmonious understanding among the Bessemer works may prevent any such calamity to this branch of the trade, but the furnace and mill men have no such safeguard.

Mr. Swank notes that in Europe the iron trade exhibited no symptoms of revival during the year 1885, the situation of the iron trade there, being worse at the close of the year than it was six months before. The extent of the depression in England will best be told in the following extract from a review of the British iron trade, in (London) *Iron*, viz.:

"The year 1885, * * * * came in with an inherited flutter of hope of better things than it had just left behind it, which hope, however, remained unfulfilled to its close. * * * * When the history of the iron trade during the last quarter of the nineteenth century comes to be written, 1885 will figure as one of the worst, if not the very worst, years of the twenty-five. At the close of 1884 we hoped, almost against hope, that the ensuing year would bring with it better times for all engaged in the iron trade.

We are free to admit that the actual result has fallen very far short indeed of any such consummation, and that, bad as trade was in 1884, it was greatly worse last year."

The Association has just published the complete statistics of the production of Bessemer steel in the United States in 1885, of which the following is a summary:

The production of Bessemer steel ingots in 1885 was 1,701,757 net tons, or 1,519,426 gross tons, an increase of 161,162 net tons over the production in 1884. The production of 1885 was the largest the country ever made. In the following table it is given in comparison with that of the three preceding years.

States.	Net Tons.			
	1882.	1883.	1884.	1885.
Pennsylvania,	933,631	1,044,396	1,031,484	1,109,034
Illinois,	397,436	273,325	339,068	366,659
Other States,	365,383	336,906	170,043	226,064
Total,	1,696,430	1,654,627	1,540,595	1,701,757

Pennsylvania made sixty-five per cent. of all the ingots produced in 1885, Illinois made twenty-two per cent., and other States made thirteen per cent. In 1884, Pennsylvania's share was sixty-seven per cent., that of Illinois was twenty-two per cent., and that of other States was eleven per cent. Included in the production of ingots in 1885 were 21,647 net tons of Clapp-Griffiths ingots, which were made by Oliver Brothers & Phillips, at Pittsburgh. This product was made from April 3d to the close of the year. No other Clapp-Griffiths plant was in operation in the United States in 1885. In 1886, there will be several in operation.

The production of Bessemer steel rails in the United States in 1885 was 1,074,607 net tons, or 959,470 gross tons, a decrease of 42,014 net tons on the production of 1884. The production of 1885 was less than in any year since 1880, when it was 954,460 net tons. In the following table, is given the production of Bessemer steel rails in this country from 1881 to 1885.

States.	Net Tons.				
	1881.	1882.	1883.	1884.	1885.
Pennsylvania,	688,276	759,524	819,544	763,223	736,522
Illinois,	346,272	336,122	231,355	290,185	308,242
Other States,	295,754	342,509	235,655	63,213	29,843
Total,	1,330,302	1,438,155	1,286,554	1,116,621	1,074,607

The figures of the output of coal during the past year will exhibit no substantial change from those of the year 1884, when about 98,000,000 tons were mined, of which approximately 31,000,000 tons were anthracite, and 67,000,000 tons bituminous and other varieties. The output of 1885, will probably be found slightly to exceed 100,000,000 tons.

From the best available sources of information, the number of miles of new railroad built during the year 1885, was 3,028, as compared with 3,950 miles built in 1884, a decrease of 922 miles, or nearly twenty-five per cent. The total railway mileage of the United States at the close of the year 1885, was 128,970 miles. The most notable event in railway construction during the past year, was the completion of the Canadian Pacific Railroad—a trans-continental line, which, it is expected, will materially aid in developing the resources of the Dominion.

The following table exhibits the number of miles built in each year, and the total mileage of the railways of the United States for a series of years:

	1878.	*1879.*	*1880.*	*1881.*	*1882.*	*1883.*	*1884.*	*1885.*
Number of miles built,	2,916	4,570	7,174	9,789	11,596	6,573	4,350	3,028
Total mileage,	81,774	86,497	97,454	103,242	114,838	121,592	125,942	128,970

The developments of the past year in relation to the progress of the interoceanic canal at Panama, have been decidedly unfavorable. Although, as usual, much of the news from this quarter was contradictory, the following statements respecting the actual condition of the enterprise, and its prospects may be accepted as substantially correct; namely; that the technical difficulties of constructing tidal basins at the termini (for which it appears no provision had been made in the original scheme), and of damming the Chagres River at Gamboa, have been greatly underestimated; that the

amount of excavation required in the gigantic cut at Culebra has likewise been underestimated by at least 20,000,000 cubic meters; that less than one-tenth of the work is yet completed; and that, finally, the original estimates of the cost of the canal ($120,000,000) by Lesseps and his colleagues have been found to be utterly inadequate, and will require to be greatly increased. It is believed that the actual expenditure thus far has exceeded $120,000,000—an amount equal to the original estimate of the cost of the entire work, and, to meet the lately developed obstacles above noted, the canal managers early in the past year applied to the French government for permission to contract a further indebtedness of $120,000,000, by the issue of a lottery loan, as was permitted in the last stages of the construction of the Suez canal.

It is understood that the French government has decided to send out an expert commission of engineers to make an exhaustive examination and to report upon the condition of the enterprise, before deciding to lend its encouragement to further expenditures.

The rival project of Capt. Jas. B. Eads, for the construction of a ship-railway across the Isthmus at Tehuantepec, has not been allowed to slumber. It has been very thoroughly discussed, both in respect to its engineering features and its commercial possibilities, before numerous institutions and public bodies. The projector has secured valuable concessions from the Mexican government, and a guarantee, for a period of years, of two per cent. interest on the obligations which the company proposes to issue to secure the funds necessary for the work. It is the intention of the projectors to ask a similar guarantee of three per cent. of the United States government. The claims are made that the interoceanic ship-railway can be constructed for a fraction of the cost of any canal that can be built; that its construction and operation involve no serious difficulties from a technical standpoint; and that the situation of the line would give it incontestible advantages, in respect to the saving of time, over all others.

Considerable progress was made during the past year on the new Croton aqueduct for supplying the city of New York with water sufficient for its present and future requirements. The total length of this structure, from Croton Dam to the Central Park reservoir, will be thirty-three and one-quarter miles; and when finished, it will have, according to estimate, a delivering capacity

of 320,000,000 gallons per day, or 100 gallons per head for a population of 3,200,000—a quantity which will provide an abundance of water for the needs of the city for many years.

On the 24th of October, which is the date of the latest accessible official returns, 22,342 feet of tunnel work had been completed, and the rate of progress was estimated at about one mile per month. It is believed that, barring accidents, the entire work will be finished in three or four years.

The removal of Flood Rock, the greatest of the remaining obstructions to the navigation of the East River, was successfully accomplished on the 11th of October. The work of tunnelling the reef had been continuously prosecuted for ten years, and at an outlay of nearly $1,000,000. To the twenty-six-foot contour the reef is about 1,200 x 625 feet, an area somewhat over six acres. It was honeycombed with about four miles of tunnels. The total amount of rock excavated aggregated 80,166 cubic yards, leaving about 275,000 cubic yards in the roof and pillars. In these there were drilled 13,286 blast holes, five feet apart in the columns and four feet apart in the roof. These averaged nine feet in depth and three inches in diameter. The explosive with which these were charged was a mixture of rackarock and dynamite, in the proportion of eight volumes of the first to one of the last. The total quantity used amounted to 283,000 pounds, all of which was exploded at once by electrical means. The volume of explosive here used exceeded sixfold the greatest charge ever previously fired. The result of the explosion is believed to have been satisfactory, though this cannot be certainly known until the work of clearing away the *débris* is undertaken.

Of foreign engineering works in course of construction, the most important are the great bridges across the Tay and the Forth in Scotland, which are progressing satisfactorily, but will not be completed for some years. The canal across the Isthmus of Corinth, referred to in last year's summary, is being rapidly advanced. The monthly rate of progress is reported to be about 120,000 cubic metres; 1,500 workmen are employed, and the work is reported to be well under way, including the breakwaters at Isthmia and Posidonia, and an iron railway bridge 141 feet above the water surface. The project of a ship canal to connect Man-

chester with Liverpool has received the sanction of Parliament. It contemplates an entrance at Eastham, near Liverpool, on the Cheshire shore of the Mersey, and a terminus at Manchester, enabling ships of the heaviest tonnage to trade direct with the latter city without the delay of trans-shipment or breaking of bulk. Great advantages to the textile industries of Manchester are expected to result from its completion.

It is interesting to note also that the Channel Tunnel project, which was supposed to have received its quietus, is again being discussed, and its projectors, it is believed, will shortly come before the British Parliament for new legislation in its behalf.

A project to construct a ship canal between the North Sea and the Baltic has at length assumed shape, and will shortly be undertaken. It is designed to be available for war and trading vessels of the largest size.

The plans for the widening of the Suez Canal, to facilitate the transit of vessels, have been agreed upon, but the actual undertaking of the work has been unexpectedly delayed.

The prospects for another Alpine Tunnel seem quite favorable. The probable location will be at the Simplon Pass. The (London) *Engineer*, referring to the probability that this work will shortly be undertaken, says that "the existing line from Geneva to Martigni and Brieg will be carried through the mountain to Domo d'Assola, and soon to Pallanza or Stresa, on the Lago Maggiore." The projected Simplon Tunnel will be at a lower level than the other Alpine tunnels, and will be longer, a rough estimate of its length being about twenty kilometres (or twelve and one-half miles), and of its cost, 100,000,000 francs.

I may note the completion of several works of the first importance. The Severn Tunnel, which was begun with the sanction of the British Parliament, in 1872, by the Great Western Railway Company, was finished toward the close of the year 1885, and was formally opened to traffic at the beginning of the year 1886. It affords an uninterrupted railway communication between England and South Wales. Its total length is 7,664 yards, or somewhat over four and one-third miles.

The Mersey Tunnel, connecting Liverpool and Birmingham, is another important engineering enterprise which was finished during the last days of the year 1885. The total length of this work is

four and one-half miles. The tunnel under the river is just one mile in length from shaft to shaft. Both of these works are of the first importance from an engineering and a commercial standpoint. Another enterprise of considerable importance, which was completed during the year, is the ship canal between Cronstadt and St. Petersburg, which was formally opened on the 27th of May last. It is 17 miles in length and 22 feet in depth, with a width of from 180 to 240 feet.

IN THE FIELD of electricity the past year may record no startling discovery, although substantial advances in certain directions were made.

In the department of telegraphy, the Phelps induction system is undoubtedly the most important invention brought out during the past year. This system renders it possible to telegraph to and from a railway train travelling at the highest speed, and it is reasonable to suppose that when its capabilities shall have been fully developed in practice, it will contribute materially to the safety of railway travel. The Harlem River branch of the New York, New Haven and Hartford Railroad has been equipped with the Phelps apparatus since the early part of the past year, and experts agree in the opinion that its practical working is satisfactory.

The year also witnessed substantial progress in perfecting and introducing the Delany synchronous-multiplex system, the Baltimore and Ohio Telegraph Company having placed New York, Philadelphia and Baltimore in connection by this system. The inventor has likewise made considerable progress in his attempts to adapt the system to the transmission of fac-simile dispatches.

In telephony, there is little of note to record. The promises held out towards the close of 1884, that the year 1885 should witness the introduction of long-distance telephony on an extensive scale, have only been partially fulfilled; nor has any substantial progress been made in placing electric wires under ground, although the question has been very widely discussed. In view of the progress in this direction that has been accomplished in Europe, the backwardness of this country is quite unaccountable. In all the more prominent cities and towns of Europe the underground system for telegraph and telephone lines is in successful operation; extensive underground land lines of telegraph have been operated for years,

and underground lines of 100 miles or more are in telephonic communication with entire success. From these facts, it would appear that we are not keeping abreast of the progress which other countries are making.

In the department of electric lighting, the most noteworthy contribution of the past year was the publication of the results of the tests of the efficiency and life-duration of incandescent lamps, and of the efficiency of dynamo-electric machines, made under the direction of the FRANKLIN INSTITUTE. These tests have been pronounced by very competent authority to be more reliable and complete than anything that has yet appeared in any part of the world in relation to the subject under discussion. They demonstrated that decided improvements have been made in the construction of incandescent lamps by which their efficiency and life-duration have been notably increased; and, in respect to the dynamo-electric machine, that this has reached so high an efficiency that but little margin for improvement remains.

The considerable extension of electric lighting, both arc and incandescent, during the past year, bears testimony to the continued popularity of these systems of illumination. In this connection, no discovery or invention of great importance is to be noted.

The friends of the secondary battery may be somewhat encouraged by the continued success which Mr. Preece, of the British Telegraph Service, claims to have obtained with them, and, in this country, with the work of Mr. E. P. Roberts, at Cheyenne, in distributing light by their use. The *Electrical World* is authority for the statement that Mr. Roberts considerably extended his plant during the year, and demonstrated that, "with intelligent handling, the secondary battery has to-day a commercial value which cannot be gainsaid."

In the electric transmission of power, the progress of the past year was somewhat more positive. Electric motors for railways have been experimentally tested in a number of American cities—New York, Philadelphia, Baltimore, Cleveland, and elsewhere—the trials of the Daft system of electric locomotion on the elevated railways of New York, and in Baltimore, having attracted widespread attention. The New York experiments do not appear to have been followed by any direct results. In Baltimore, however, the Daft system has been in actual operation since September 1,

1885, on one of the suburban lines of surface railroad (the Baltimore and Hampden Railway). This road was originally a horse railway, and is a feeder of one of the principal lines of street railway in that city. It is about two miles long. Two Daft motors are in use, each rated at ten horse-power, and regular hourly trips are made from one terminus to the other. The system is reported to be working satisfactorily. In Cleveland, on the other hand, where the first experimental trials with the electric railway in this country were made, the latest accounts report that the electric system has been abandoned. Worthy of special note, also, are the researches and experiments of Deprez in connection with the subject of the electric transmission of power over long distances. As the result of experimental trials recently carried on at Creil, in France, Deprez asserts that he has succeeded in transmitting forty horse-power over a distance of more than twenty miles, with an efficiency approximating closely to fifty per cent. The prospect which such a result holds out, of advantageously utilizing the almost unlimited supplies of water-power, which can be made available for the purpose in numberless localities, is highly suggestive.

It is, however, in the department of electro-metallurgy that the most signal advance was achieved during the past year. The invention here referred to is that of the Cowles Brothers, of Cleveland, O. These gentlemen have succeeded in constructing a smelting furnace in which the intense heat of the voltaic arc is applied far more efficiently than has heretofore been found possible, and with which they have succeeded in easily effecting the reduction of the most refractory substances. The essential feature of the Cowles system consists in utilizing the well-known intense heating effects obtainable with the electric current to reinforce the reducing action of carbon. They place in a suitably constructed furnace a mixture of granulated ore and carbon, and pass through this the current of a powerful dynamo. The temperature attainable in this furnace—due to the resistance of the carbon fragments—is said to be so high, that such difficultly-fusible metals as platinum and iridium are instantly melted; and the highly refractory compounds of many substances, such as silicium, boron, magnesium, aluminium, etc., which, under ordinary circumstances, are not decomposed by carbon, are readily decomposed and these substances reduced to their elemental state. The technical and commercial

success of this most interesting process seem to be fully assured. It promises to give to the constructive arts a number of new and useful alloys, and, unless all indications are misleading, it will give the world what has long and vainly been sought for—cheap aluminium. Dr T. Sterry Hunt, whose opinion is entitled to the highest respect, and who has had the opportunity of making a personal investigation of the merits of this invention, believes that it marks the beginning of a new era in the metallurgical arts.

IN METALLURGY, commendable progress has been made in the direction of simplifying the processes and cheapening the cost of producing steel. Four processes of this nature have attracted much attention. These are known, respectively, as the Clapp-Griffiths, the Davy, the Gordon, and the Avesta. They are all outgrowths of the pneumatic, or Bessemer process, the substantial difference residing in the manner of applying the blast or tuyeres.

The Clapp-Griffiths process is the most promising of these processes. Messrs. Oliver Brothers & Phillips, of Pittsburgh, were the first to introduce this process, and their plant has been in constant operation since the spring of 1885. These works comprise two three-ton converters, with necessary accessories, having an estimated capacity of producing 150 tons of ingots in twenty-four hours.

THE FAVORABLE comments expressed in last year's summary on the importance of the introduction of natural gas in its bearing on the industries of Pittsburgh and vicinity, prove to have been entirely justified. During the past year, the changes which its introduction has brought about, may properly be characterized as a revolution in industrial and domestic economy. It has practically superseded coal for nearly all manufacturing purposes, and has come to be largely used for domestic heating. The difficulties and dangers resulting from the enormous pressures at which the gas issues from the wells have been practically overcome by the adoption of mechanical artifices, by which the pressure in the mains is reduced to a few pounds, and in the service pipes to a few ounces. At present, three important companies control the supplies of natural gas in Pittsburgh and its suburbs—the Philadelphia (Westinghouse) Company, whose pipe system covers Pittsburgh and Alleghany City; the Chartiers Valley Gas Company,

whose service pipes are intended to supply the mills on both sides of the Monongahela River; and the Alleghany Heating Company, which supplies Alleghany City with gas furnished by the first-named company. At last advices, the total mileage of pipes laid is about 600 miles. The pipes range from six to twenty-four inches in diameter. The mains leading from the wells are wrought iron pipes, from ten to sixteen inches in diameter. The lines used through the city are twenty and twenty-four-inch mains, from which a network of six, eight, ten and twelve-inch service lines branches off to supply domestic consumers. The gas piped to the city represents the total product of about fifty wells.

Natural gas is now used in most of the iron, steel, copper, brass and other metal-working establishments; in all the glass factories (about seventy in number); in all the hotels; and is rapidly coming into use for domestic service. The price charged to manufacturers varies according to their consumption, being, in the case of iron and steel, so much per ton of finished product. The number of domestic consumers is rapidly increasing, and, it is estimated that at the close of the year no less than 1,000 dwelling houses were supplied with gaseous fuel. The rate charged for this class of consumers is, in Pittsburgh, a fixed sum per house, and in Alleghany City, ten cents net per 1,000 cubic feet.

The new fuel has been in use long enough to demonstrate that coal can largely be dispensed with in Pittsburgh and vicinity. The amount of coal displaced by gas already exceeds 10,000 tons daily, the equivalent of the output of 2,500 miners. The direct result has been the abandonment of a number of the mines heretofore worked to supply the Pittsburgh market, and a fall of thirty-five to forty per cent. in the price of coal. The superiority of the gaseous fuel over coal, because of its greater purity and the more perfect control of the heats, has been fully demonstrated, and the general result is, not only that a better quality of iron, steel and glass can be made than from coal, but the economy in cost is so marked that the manufacturers of this favored region have decidedly the advantage of their less fortunate competitors away from the gas belt.

Whether or not it will be found practicable to pipe the gas to considerable distances, or even, as has been suggested, as far as the great seaboard cities, is problematical. The question of the

permanence of the supply also is one which is involved in some uncertainty, though on this score but little uneasiness appears to be felt.

The opinion of those best informed seems to be that when once accustomed to gaseous fuel, neither manufacturers nor domestic consumers will willingly return to the use of coal. The future probabilities are well summarized in the following terms by one of the best informed journals: "In case the wells should fail, of which there is no present prospect, it is already settled that some form of fuel-gas will be manufactured to take its place. The Westinghouse Company has had some such contingency in view, and should the wells cease to give their supply, their large pipe lines can be used in the distribution of artificial fuel-gas. Western Pennsylvania has millions upon millions of tons of refuse coal, or 'slack,' which can be manufactured at the mouths of the coal-pits at very small cost, and with proper machinery forced through the pipes to the consumers; or, what is more to the purpose, water-gas can be manufactured and delivered to the consumer at a cost but little in excess of the price now charged for natural gas, the estimated cost being about ten cents per 1,000 feet."

One of the indirect consequences of the introduction of natural gas in the Pittsburgh region, has been to direct attention in other industrial centres to the question of the feasibility of introducing artificial fuel-gas; and it is quite probable that in the near future a number of experiments of this nature will be undertaken. In this connection it may not be amiss to note the fact that the admirable exposition of the capabilities of water-gas made at the Novelties Exhibition of the FRANKLIN INSTITUTE, in Philadelphia, and which, in respect to completeness and variety, far surpassed anything of the kind heretofore attempted, has contributed very materially to the education of public opinion on this important question.

OF considerable technical interest, likewise, is the report of a special committee of the American Society of Civil Engineers, on the subject of the preservation of timber, which was made public last summer. This committee, after a very exhaustive examination of all accessible data, reports very positively in favor of the economy of wood preservation. In Europe, the testimony on this point is

very decided. In this country wood preservation is in the experimental stage, but, in the committee's opinion, the time has arrived when, in many sections, an economy of from twenty to fifty per cent. will result from the preservative treatment of cross-ties and timber structures, while in other sections timber is still too cheap to warrant the expense of such treatment. On the question of the selection of the preservative, the committee reports that, if the timber is to be placed in sea water, where it will be exposed to the attacks of the teredo and other boring mollusks, creosote, or "dead oil" is the only reliable antiseptic. For railway cross-ties, the committee believes that creosote is likewise the most efficient preservative, but on account of its cost it recommends, as more advisable, the use of chloride of zinc (burnettizing). For bridge-timbers, trestles, and other service, where the timber is exposed in comparatively dry situations, it recommends kyanizing (treatment with corrosive sublimate) as the most expedient method.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS OF THE FRANKLIN INSTITUTE, ON THE DELANY SYSTEM OF SYNCHRONOUS MULTIPLEX TELEGRAPHY.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 12, 1884.

The Committee of the Electrical Section acting as a Subcommittee of the Committee on Science and the Arts, to which was referred, for examination,

"PATRICK B. DELANY'S SYSTEM OF SYNCHRONOUS MULTIPLEX TELEGRAPHY,"

respectfully presents the following report, viz.:

Multiplex telegraphy, or the simultaneous transmission of several messages over one line, has been accomplished in several ways with greater or less success. At least three methods are now in use commercially.

(1.) The Duplex and Quadruplex Systems, which are operated by the differential method;

(2.) The Harmonic System, by which several sets of vibrations are set up in the line circuit at different rates of speed; and

(3.) The Synchronous Systems, which transfer the line rapidly to different sets of instruments in rotation. The synchronous system of Mr. Delany belongs to the latter class.

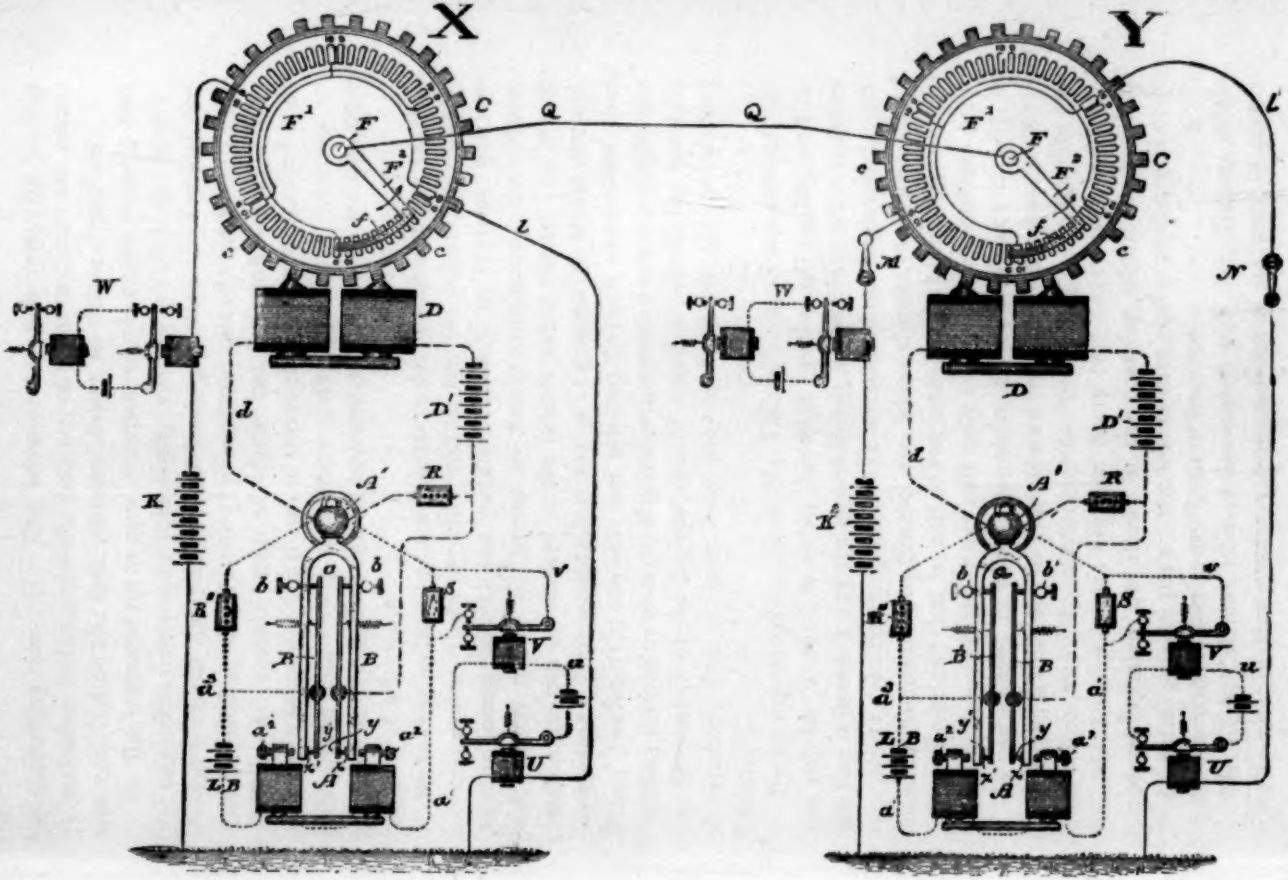
The basis of the synchronous systems is that the moving parts of two instruments, one at each end of the line, shall revolve in exact unison with each other. The difficulty in maintaining the unison under all the conditions of commercial telegraphy, has prevented their adoption commercially, except in the case of the Baudot and the Mayer synchronous systems, which have met with some degree of success in France, and notably on a line between Paris and Marseilles. Mr. Delany's system is based on the phonetic wheel of Paul La Cour, of Copenhagen. This consists of an electro-magnet and a toothed wheel of iron, the teeth or cogs of which, as it rotates horizontally, pass in front of the poles of the electro-magnet. The circuit of the electric-magnet is broken through the medium of the vibrations of a tuning fork; the fork is vibrated by the intermittent pulls of another electro-magnet, whose circuit is also broken by the vibrations of the tuning fork; the toothed wheel, therefore, receives as many pulls per second as the number of vibrations of the tuning fork, and is thus revolved at a uniform rate of speed.

In adapting this wheel to multiplex telegraphy, a trailing arm is attached to the revolving wheel, which is made to pass over a series of contacts arranged as segments of a circle which are insulated from each other. The trailing arm is connected with the line, and, as it rotates, connects the line with each of the segments, one after the other. These segments are in circuit with telegraphic instruments, which are thus successively put in electrical connection with the line. At the other end of the line, there is a similar distributor, with its trailing arm, which connects, in rotation, the same number of segments to the line. If, now, the two distributors revolve in unison, it is evident that corresponding segments at each end of the line will be connected with it simultaneously; when No. 13 segment, for instance, is connected through the trailing arm at one end, No. 13 segment at the other end is also electrically connected, and impulses can be sent from one to the other.

The art had advanced to this stage when Mr. Delany commenced his investigations. It was found that no two tuning forks

could be so accurately attuned that they would vibrate in unison. But it was also found that by increasing the strength of the fork circuit, thus strengthening the magnet which vibrated the fork, its tines would be pulled wider apart and the vibrations would be slower. Making use of this principle, Mr. Delany inserted in the circuit of the magnet of the vibrating fork, a resistance coil, which could be automatically cut out when the vibrations were too rapid, thereby strengthening the current of the magnet, and making the wheel revolve slower. Certain segments in the circle of contacts at each end of the line were used to transmit and receive electrical impulses, which operated to cut out this resistance coil whenever its wheel revolved at a greater rate of speed than the wheel at the other end of the line. Three of these segments are receiving segments, and three are transmitting segments, and as the trailing arm revolves at the rate of nearly three times per second, means are thus provided for about sixteen or seventeen corrections of the movement of the wheel per second. These impulses are sent upon the slightest tendency of one wheel to run faster than the other. Each transmitting segment has its corresponding receiving segment at the other end of the line. When the wheels are exactly in unison, no current passes over the line through these segments, but when the trailing arm at the receiving station is in the slightest degree in advance of the arm at the transmitting station, the circuit is completed, and a correcting impulse is transmitted.

In the accompanying drawings, two sets of instruments, *X* and *Y*, represent two stations electrically connected by a telegraph wire. In the circular table of contacts, there are six independent sets or series. The *9's* and *10's* of each series are used for correcting impulses only. Three of the *9's* on *X*, taken alternately, are connected together, and through a battery to the ground. The corresponding *9's* on *Y* are not connected with anything, but are "dead." The three *10's* following the three dead *9's* are connected together, and thence through a correcting relay, *U*, to the ground. It will be observed that the surface of the three receiving *10's* is extended towards the preceding dead *9's*, making a broad segment. If, now, when the arms, *F*, are revolving, the trailing arm *f*, at *Y*, should reach the broad segment *10* before the trailing arm *f*, at *X*, had left the battery connected *9*, it is evident that an impulse will be sent through the line, which will energize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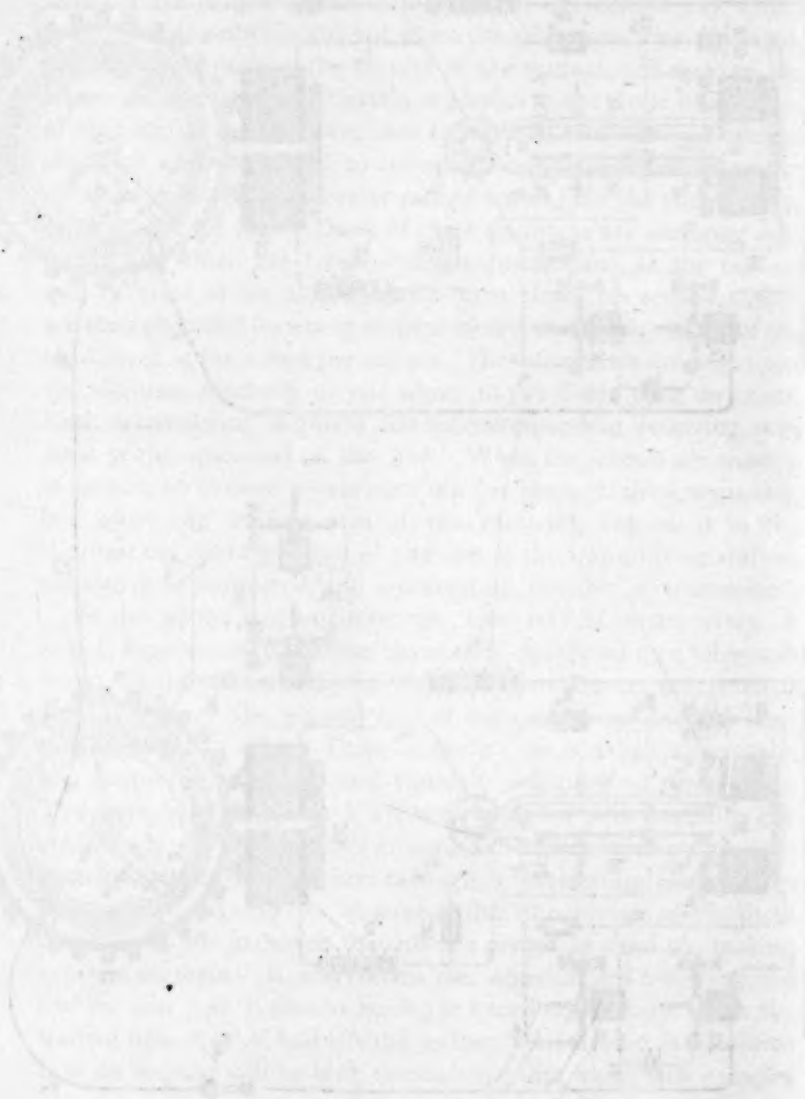

the correcting relay, *U*. The armatures of this relay, by leaving its back-stop instantaneously, cuts out of the fork circuit the resistance coil, *S*, and the fork vibrates slower, as before described.

In the instruments as now constructed, there are seventy-two (72) segments devoted to telegraphy, each of which is put in connection with the line nearly three times per second. The line can thus be used as seventy-two (72) separate circuits for step-by-step printing instruments, each of which can transmit three or four words per minute. Or, if two of the segments are connected with each printer employing one–thirty-sixth ($\frac{1}{36}$) of the wire, six or eight words per minute can be transmitted, and so on for a greater number of segments.

By taking as many as six segments, for instance, every twelfth, and connecting them together and to one instrument, the instrument is connected with the line about seventeen (17) times per second, which makes a current so nearly continuous, that Morse instruments can be worked at the rate of about twenty (20) words per minute. This would allow twelve (12) separate Morse circuits. When twelve (12) contacts are allotted to each instrument, thus dividing the line into six (6) Morse circuits, each one of the six circuits can be worked at the highest rate of speed of which the operator is capable; that is, from forty (40) to forty-five (45) words per minute.

By an ingenious device of Mr. Delany's, these separate circuits can also be worked in either direction with equal facility, so that the line is in every way the equivalent of six separate wires between two points. In this respect it is in advance of the duplex and quadruplex systems now in general use, whose circuits can only be used in one direction; that is, half of the circuits can be worked only in one direction, and the other half only in the other direction.

In any system in which the main circuit is broken rapidly, as in this one, a difficulty is experienced from the static charge of the line, which seriously interferes with its working. To remedy this evil, Mr. Delany inserts between every two instrument segments, a ground segment, not shown in the drawing, which is connected to a central ground plate; the line is thus partly discharged of its static electricity after every battery impulse.

Mr. E. A. Calahan, who is associated with Mr. Delany in the development of this system, introduced one of its most important

features, which is the use of a polarized relay in connection with the Morse method. As this relay responds only to alternate currents of an opposite character, the hitherto insurmountable difficulty of eliminating from the signals the rapid makes and breaks caused by the transfer of the line from one circuit to another, is entirely overcome, and the signals are as clear and sharp as if transmitted over an independent wire.

The line is worked on what is known as the open-circuit principle; that is, the line at the receiving end is connected with the ground through the relay, without battery, and the key of the sending instrument gives alternate positive and negative currents from the battery. One great advantage of the open circuit is, that the greater portions of the evils resulting from defective insulations are eliminated, as, if a sufficient amount of electricity passes over the line to operate the relay at the receiving end, no adjustment of the relay is required to neutralize the effects of a variable current. It may be said to be independent of any variation in the current through leakage, always provided enough current reaches the instrument to operate it.

After holding several meetings, the committee visited the inventor's laboratory in New York, and saw the system in operation over a short wire, both terminals being in the same room. The conditions of an ordinary commercial line were simulated as far as possible by the use of resistance coils, artificial leaks and condensers, and although the instruments worked quite satisfactorily under several severe tests, it was thought best to make no report until a test had been made on a commercial line then being constructed, which was completed in June last, between Boston and Providence.

Soon after the completion of this line, a series of tests extending over several days was made, under the supervision of a member of the committee, first over the line fifty (50) miles long, using the earth for return circuit; and next by looping two wires, making a distance of one hundred (100) miles.

The loop in this case was not used as a complete metallic circuit, but the two ends were grounded at Boston on different earth-plates.

The conclusions arrived at may be stated generally, as follows:

(1.) That the synchronism of the instruments will be main-

tained over that length of line under any conditions which would allow a Morse relay to be successfully worked.

(2.) That in the rare instances in which the synchronism is seriously disturbed, it is restored automatically in from one to three minutes, or it can be restored sooner by proper manipulation by a skilful operator.

(3.) That no adjustment of the relays is required in wet weather, or on account of variable currents.

A public test was made, on which occasion six Morse operators in Boston, and six in Providence, simultaneously worked their respective instruments. On the first test, the six Providence men sent press dispatches simultaneously to the Boston men. In the second test, the Boston men sent dispatches to Providence, and in the third test, three men were sending and three receiving at each end of the line. In all these tests the amount of business done over each circuit was proportioned to the ability of the operators on that circuit. Two first-class men on one of the circuits sent and received as high as forty-three words per minute.

Other experiments were made with five Morse circuits, having twelve contacts each, the remaining twelve segments being attached to twelve printing instruments, all of which were worked successfully, simultaneously with the Morse circuits. A test of the line divided into twelve Morse circuits, each having six contacts, was also made, and a speed of twenty-one words per minute, was attained on a test lasting over an hour.

During the recent Electrical Exhibition, the instruments were worked over a line two hundred miles long, of No. 8 iron wire, with satisfactory results.

The only question to be determined by this experiment was whether the static charge of a line of this length would be discharged soon enough to leave the line free from the succeeding battery charge. The experiment was made with two hundred and forty cells of Callaud battery, divided into two batteries (positive and negative) on one end of the line, and with two batteries of forty-eight Fuller cells each, on the other end. In working from the Fuller end of the line the results were perfectly satisfactory, but in working from the Callaud end, there was a retardation in the signals.

The committee recognizes the fact that the practically perfect synchronism attained by this invention is a most important advance in the art of telegraphy. With synchronism many other things are possible, and it seems quite probable that its uses will not long be confined to the two systems of telegraphy herein described, or even to telegraphy alone. The committee is impressed with the importance of this invention, and unanimously recommends the award of the "Elliott Cresson Gold Metal."

(Signed)

W. W. GRISCOM, *Chairman,*
CHARLES M. CRESSON, M. D.,
ADDISON B. BURK,
W. J. PHILIPS,
ALEX. E. OUTERBRIDGE, Jr.,
E. ALEX. SCOTT, *Ex. Off.*

At the stated meeting of the Committee on Science and the Arts, held Wednesday, March 4, 1885, this report was amended by the incorporation of a recommendation of the award of the "Elliott Cresson Medal and of the John Scott Legacy Premium and Medal," to P. B. Delany; and a recommendation of the award of the "John Scott Legacy Medal and Premium," to E. A. Calahan, and, as so amended, was adopted.

(Signed) H. R. HEYL, *Chairman.*

Adopted March 4, 1885.

A NEW ORDER OF METALLIC SPECTRA.—When, in observing the spark spectra of solutions of metals of the didymium and yttrium families, the liquid itself is made the positive pole, the upper surface of the liquid becomes luminous and gives a spectrum consisting of several nebulous but sometimes brilliant bands lying between 6205 and 4765. Boisbaudran could not trace this spectrum to any of the known cerite metals, and he was unable to obtain it with solutions of the yttrium compounds. It is, however, identical with the bands given by the phosphorescence of pure yttrium compounds, as observed by Crookes, in high vacua. The direct contradiction between these observations will be made the subject of further experiments.—*Jour. Chem. Soc., Sept., 1885.*

AGE OF FOREST TREES.—John T. Campbell reports some interesting observations upon the age of trees, which throw discredit upon the theory that wide, annual rings denote moist and fruitful years, and narrow rings indicate dry years. He finds that two neighboring trees, of the same description and the same age, will have rings of different characters in the same season. The healthiness of the tree, the amount of sun and moisture that it receives, the attacks of insects, the amount of suitable nourishment in the soil, etc., influence the amount of annual growth.—*Amer. Naturalist, Sept. 1885.*

Franklin Institute.

[*Proceedings of the Stated Meeting, Wednesday, March 17, 1886.*]

HALL OF THE INSTITUTE, March 17, 1886.

COL. CHAS. H. BANES, President, in the Chair.

Present—137 members and twelve visitors.

The Actuary reported the election of fifteen persons to membership.

The President made a report of progress on behalf of the Special Committee charged with the work of formulating plans for the future development of the INSTITUTE, and for a new building. He invited members present to submit suggestions, which would receive the respectful consideration of the committee.

MR. JOHN SHINN, of Philadelphia, read the paper of the evening, on "The Cultivation of Flax in the United States." The speaker made an earnest plea for the establishment of the manufacture of the finer grades of linen in the United States. The paper provoked an extended discussion.

On Mr. Burleigh's motion, seconded by Mr. Orr and others, the thanks of the meeting were presented to Mr. Shinn for his interesting and instructive paper. The paper has been referred for publication.

The Secretary's report embraced remarks on the following topics: the Transmission of Power by Electricity: the Smith, Edison and Gilliland System of Telegraphing to and from Railway Trains in Motion, by utilizing the principle of Static Induction, and the uses of Aluminium Alloys in the Production of Wrought Iron (or Mitis) Castings. The following inventions were shown and described: John H. Miller's System of Constructing Air Chambers of Pumps, for Aërating Water under Pressure, etc., P. J. Grau's Improvement in Feed Water Purifiers and the Magnesia Sectional Covering Company's Covering for Steam Pipes.

The Secretary exhibited with the stereopticon, and described, a suite of five photographic views taken in the Caverns of Luray, which were presented to the INSTITUTE by Mr. C. H. James.

Adjourned.

WM. H. WAHL, *Secretary.*

A TERTIARY RAINBOW.—Prof. Tait remarks that rainbows due to three or more internal reflections "are too feeble to be observed." It may, therefore, be worth while to record a tertiary bow, which was clearly seen from Thandiani Hill, in the Punjab. The bow extended over an arc greater than a semi-circle, but was broken in two places. The colors were as distinct as in many an ordinary bow. The condition of the sky was specially favorable for seeing a tertiary bow. The sun was low and on nearly the same level with it there were several horizontal layers of cloud of considerable extent, whose nearer, unilluminated sides were therefore dark enough to serve as a good background. There was also a cloud in front of the sun itself, partially reducing its brightness.—*Nature, Oct. 1, 1885.*

BOOK NOTICE.

NOTES ON THE CHEMISTRY OF IRON. By Magnus Troilius, E. M. New York: John Wiley & Sons. 1885.

We have read with considerable interest the "Notes on the Chemistry of Iron" by Magnus Troilius, E. M., and although we have been unable to find anything strikingly new or original, yet the author has so successfully culled, from a vast amount of scattered information on the subject, all the essential requisites for a complete system of iron and steel analysis, that few workers in that field can afford to do without this valuable contribution to the literature of the subject.

It would be highly advantageous to the profession, for specialists in the various branches of Analytical Chemistry to publish just such "Notes." They are far more valuable to the worker than the more pretentious works can hope or expect to be, for it is from just such "Notes" that the larger works on chemistry are compiled; and it is in discarding the details of the *modus operandi* of various methods that they lose their value. It too frequently happens that authors are not familiar personally with the methods they describe, and therefore omit what appear to be trifling minutiæ, but which in reality (once the principles have been mastered) are essentials. For it is in the accumulated knowledge of a vast number of experiments made under the same conditions; or, in other words, the results of experience, that the advantages of a particular method are to be found, and these advantages constitute the "wrinkles" of the most experienced chemists. In these days of specialties, it is well-nigh impossible for a chemist to be posted in all the branches of that complex science, but he is frequently called upon to work in fields where he has had only the most superficial experience. In such cases "Notes" similar to those Mr. Troilius has published, for example, "Wanklyn's Water and Milk Analysis," and Hempel's "Neue Methoden für Analyse der Gase," are exceedingly valuable. We feel that they are thoroughly reliable and therefore authoritative.

We believe it would have been in better taste for Mr. Troilius to have given personal credit for the various methods and apparatus proposed and designed by others.

The platinum tube for carbon combustions we believe was first used and described by Mr. Andrew Blair, of Philadelphia, and the methods described for determining phosphorus and manganese are due to Dr. Tamm and Mr. Ford, respectively. We must also enter our protest to the sweeping assertion that "the disadvantages of the permanganate solution are so great, that it has almost everywhere been abandoned in favor of the bichromate" We believe that nine chemists out of ten, at least in this country, use the permanganate solution in the determination of iron.

These, however, are not vital matters, and, taken altogether, we must congratulate Mr. Troilius on having supplied a long-felt want, and we hope that his little book will have the full measure of success that it certainly deserves.

P. G. S.

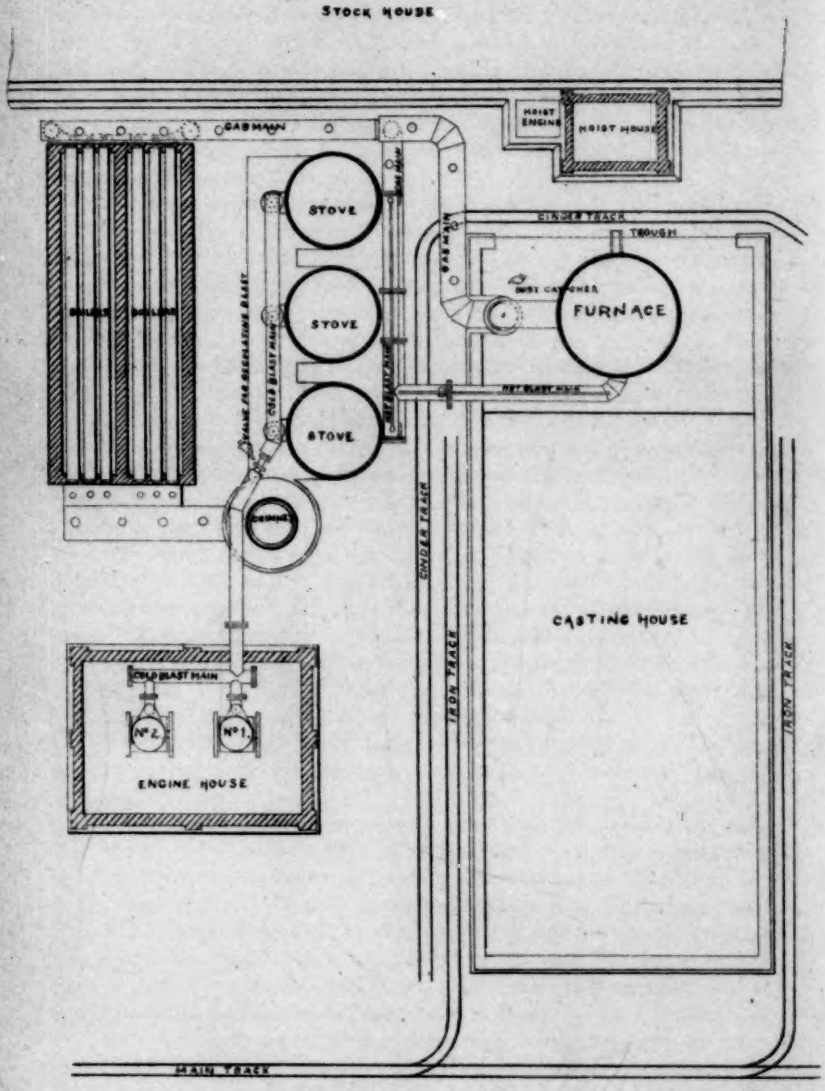

PLATE I.

ARRANGEMENT FOR A FURNACE PLANT.

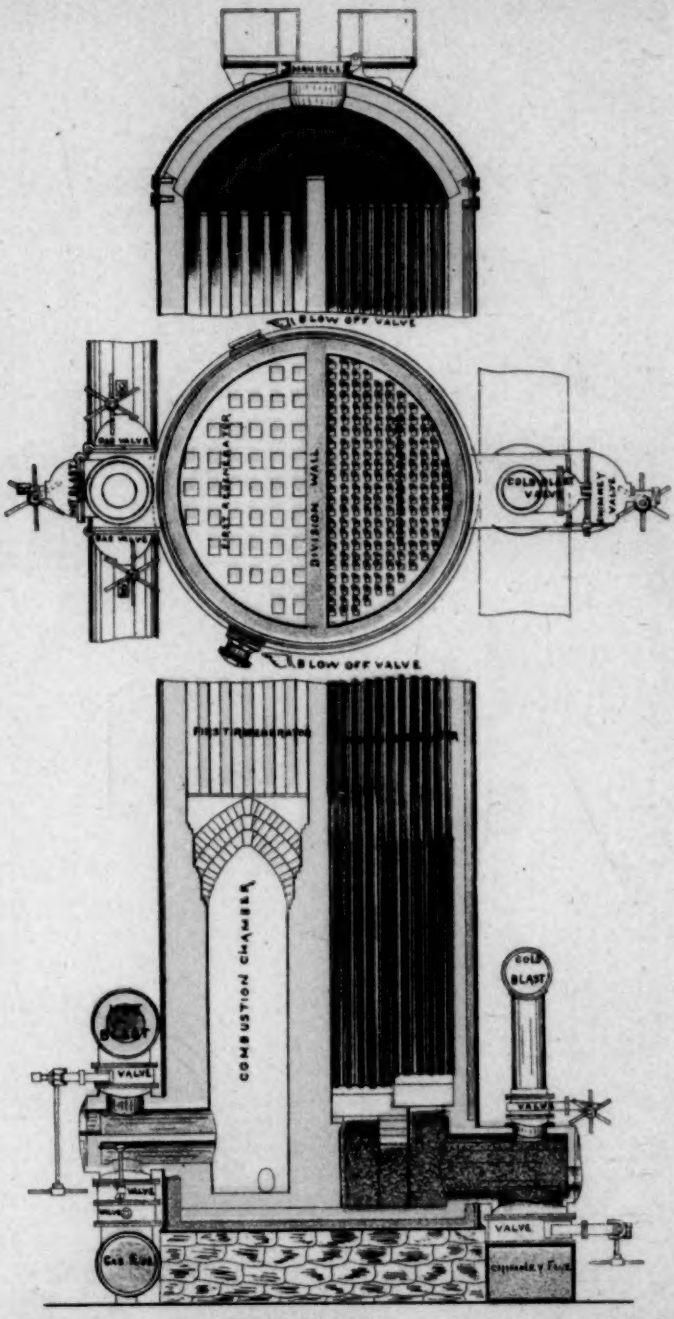
BLOW OFF VALVE
DIVISION WALL
BLOW OFF VALVE
COMBUSTION CHAMBER
COLD BLAST
VALVE
VALVE
VALVE

PLATE II.

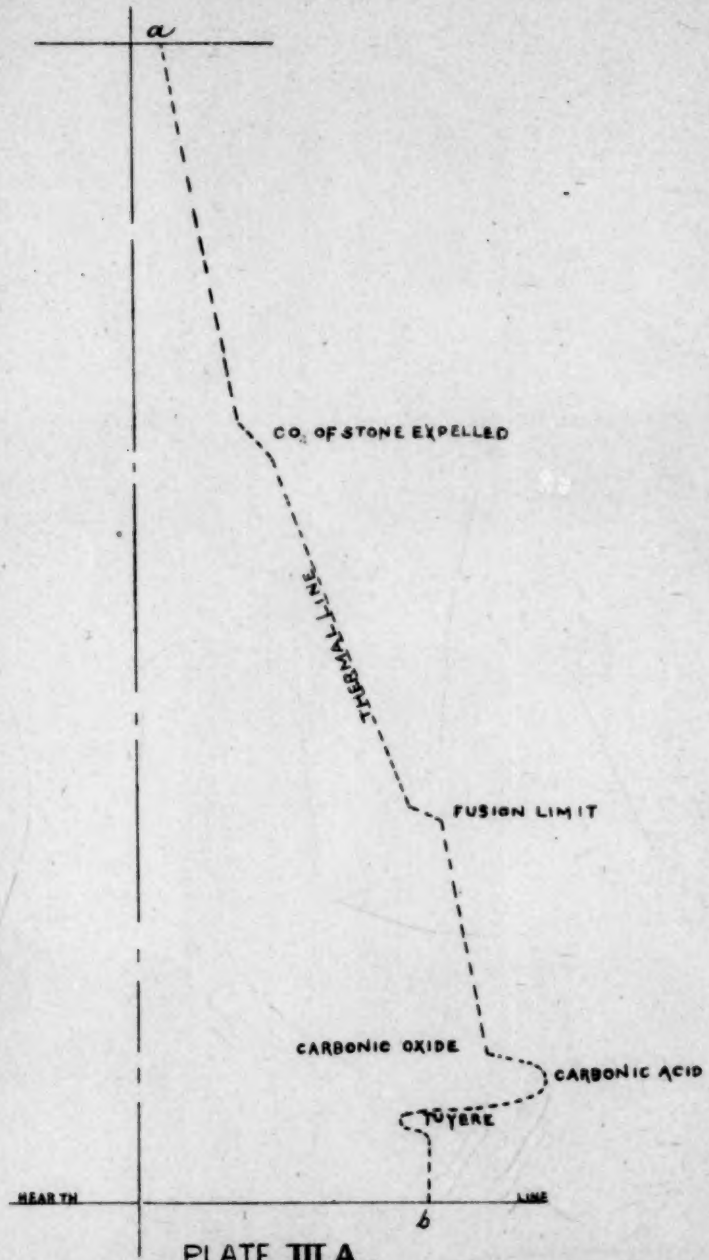
a
CO. OF STONE EXPELLED
THERMAL LINE
FUSION LIMIT
CARBONIC OXIDE
CARBONIC ACID
TUYERE
HEARTH
LINE
b

PLATE III A.

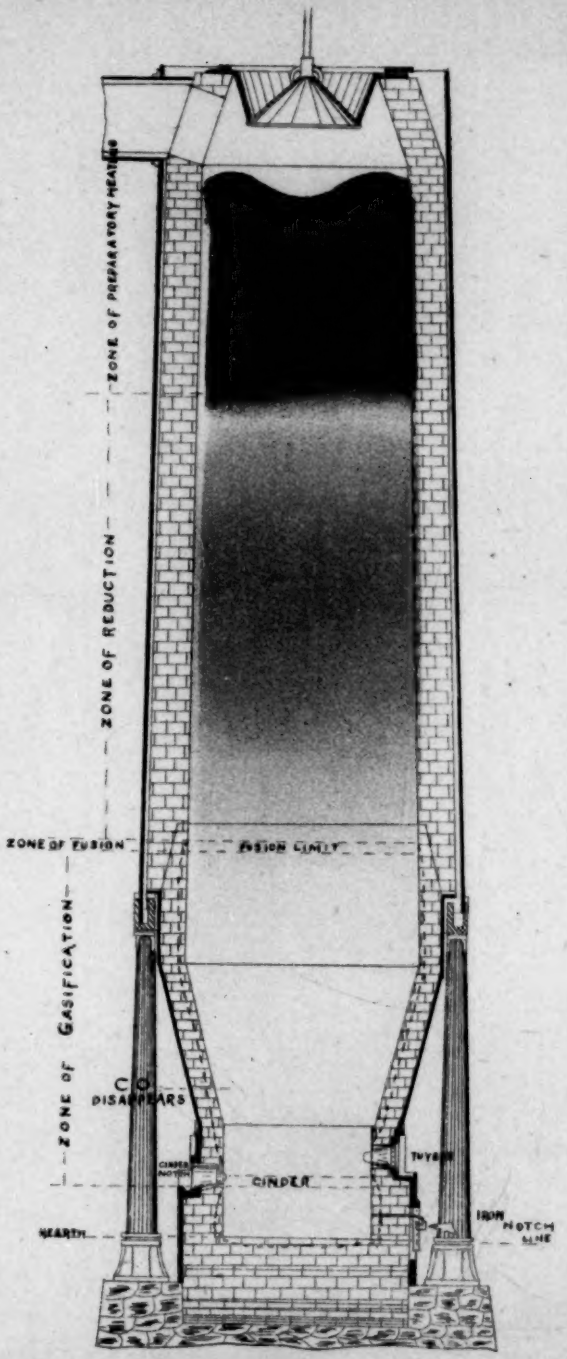
ZONE OF PREPARATORY HEATING
ZONE OF REDUCTION
ZONE OF FUSION
FUSION LIMIT
ZONE OF GASIFICATION
CO
DISAPPEARS
CINDER NOTCH
CINDER
TUYERE
HEARTH
IRON NOTCH LINE

PLATE III.

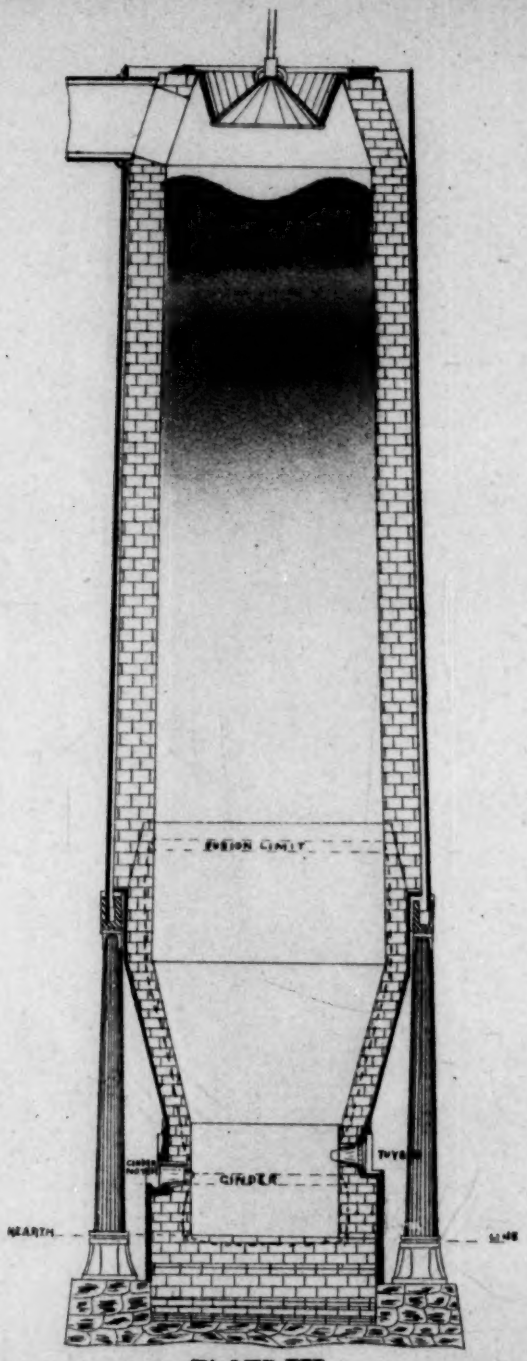

PLATE IV.

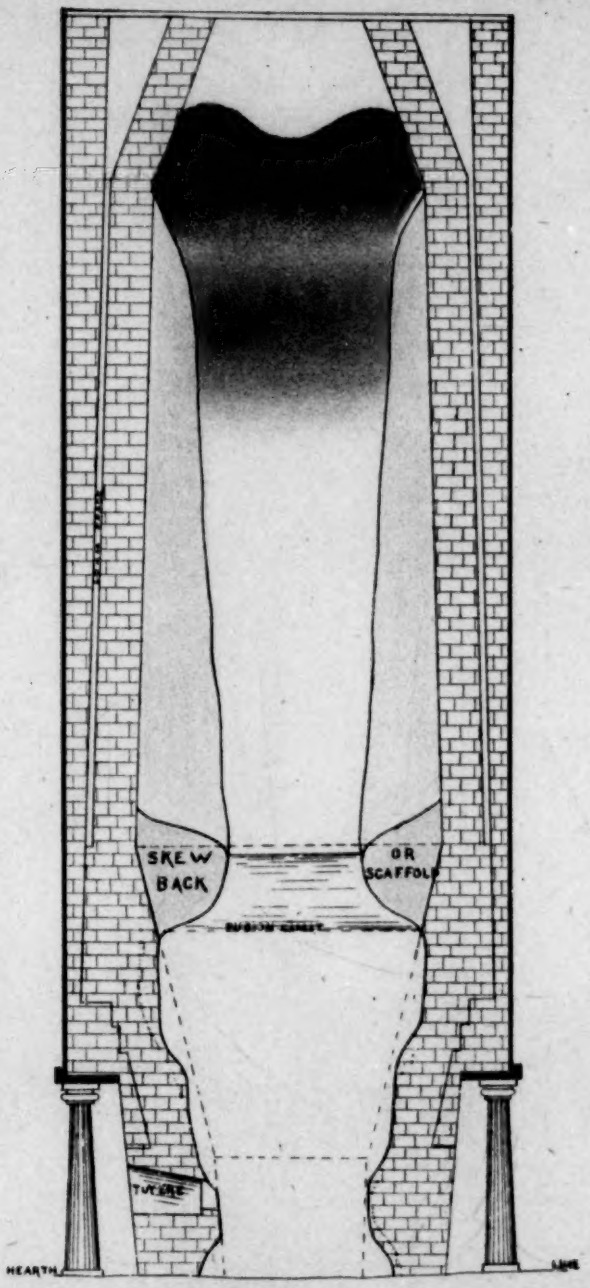

PLATE V